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Environmental Data Package for ORNL Solid Waste Storage Area Four, the Adjacent Intermediate-Level Liquid Waste Transfer Line, and the Liquid Waste Pilot Pit Area

E. C. Davis
R. R. Shoun

Environmental Sciences Division

Publication No. 2788

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ENVIRONMENTAL SCIENCES DIVISION

ENVIRONMENTAL DATA PACKAGE FOR ORNL SOLID WASTE STORAGE AREA FOUR, THE ADJACENT INTERMEDIATE-LEVEL LIQUID WASTE TRANSFER LINE, AND THE LIQUID WASTE PILOT PIT AREA

E. C. DAVIS and R. R. SHOUN*

Environmental Sciences Division
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*Chemical Technology Division.

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NUCLEAR AND CHEMICAL WASTE PROGRAMS
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ABSTRACT

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The Oak Ridge National Laboratory Remedial Action Program has determined through its review of past environmental studies that Solid Waste Storage Area Four (SWSA-4) continually releases radioactivity to White Oak Creek and therefore requires application of the site stabilization and remedial actions outlined under the 3004u provisions of the Resource Conservation and Recovery Act. Under these provisions, a Remedial Investigation/Feasibility Study (RI/FS) forms the basis for determining the extent of actions. This report assembles available historical and environmental data relative to the SWSA-4 waste area grouping (WAG), which includes the 9.3-ha SWSA-4 site, the adjacent abandoned intermediate-level liquid waste transfer line, and the experimental pilot pit area. The rationale for grouping these three waste management units into the SWSA-4 WAG is the fact that they each lie in the same hydrologic unit and share a common tributary to White Oak Creek.

The results of this compilation demonstrate that although a considerable number of studies have been carried out in SWSA-4, needs such as installation of water quality wells and continued monitoring and reporting of hydrologic data still exist. These needs will become even more critical as the RI/FS process proceeds and remedial measures for the site áre considered. Fewer studies have been carried out to characterize the extent of contamination at the waste transfer line and the pilot pit area. Alternatives for characterizing and stabilizing these two minor components of the SWSA-4 WAG are presented; however, extensive remedial actions do not appear to be warranted.

1. INTRODUCTION

The Oak Ridge National Laboratory (ORNL) Remedial Action Program (RAP) was established to provide comprehensive environmental management of all inactive contaminated sites at ORNL. Since the inception of the program in 1985, the remedial action strategy has followed the guidance of DOE Orders for Surplus Facilities Management (DOE 5820.2) and implementation of the DOE CERCLA Program (DOE 5480.14). As a part of this effort, individual sites were being addressed on a priority basis in terms of site characterization, closure planning, and remedial actions. Integration of these individual actions was to be provided through a comprehensive site-wide environmental assessment, leading to the development of an Environmental Impact Statement (EIS) for remedial actions in the White Oak Creek Watershed.

Recent Environmental Protection Agency (EPA) requests for project schedules under the 3004u provisions of the Resource Conservation and Recovery Act of 1976 (RCRA) have resulted in the need for modifying the ORNL RAP strategy. Under these provisions, any person seeking an RCRA permit for a hazardous waste management unit must adhere to the corrective action sections of the 1984 RCRA reauthorization (section 3004u). Such actions will be required for all releases of hazardous waste or constituents from any solid waste management unit, regardless of when the waste was placed there.

Under the 3004u provisions, a Remedial Investigation/Feasibility Study (RI/FS) process forms the basis for determining the extent of contamination problems and the scope of the needed corrective actions. This process begins with the identification of sites either known to exhibit continuing releases or with the potential to do so, followed by extensive site characterization and assessment. The final product of the RI/FS is a comprehensive assessment of the available alternatives for remedial actions and a recommendation for follow-on implementation.

This report addresses one of ORNL's Waste Area Groupings (WAG-4), [Solid Waste Storage Area Four (SWSA-4)], and includes (1) the 9.3-ha waste disposal area, (2) a portion of the adjacent intermediate-activity low-level liquid waste transfer lines that were used to transport liquid waste from ORNL to the Pits and Trench Area located in Melton Valley, and (3) the experimental Pilot Pit Area (Area 7811) (Fig. 1). The latter two inactive facilities have been included in the WAG-4 because of their close proximity and the fact that they are in the same hydrogeologic unit.

The objectives of this report are (1) to assemble background operational and environmental information on each of the three facilities making up the WAG-4 and (2) to develop the foundation for a future environmental characterization plan that can be implemented to begin data collection activities required by the RI/FS sequence. Past work in SWSA-4 has indicated that radionuclides are migrating from the buried waste to White Oak Creek, making this site of concern to the ORNL RAP Program. On the other hand, little is known about potential environmental hazards of the abandoned intermediate-activity low-level liquid waste transfer lines and the Pilot Pit Area. It is anticipated that through the data collection and review process outlined in this report, a decision can be made regarding the relative importance of these two inactive facilities (compared with SWSA-4) and the need to pursue future stabilization and remedial actions.

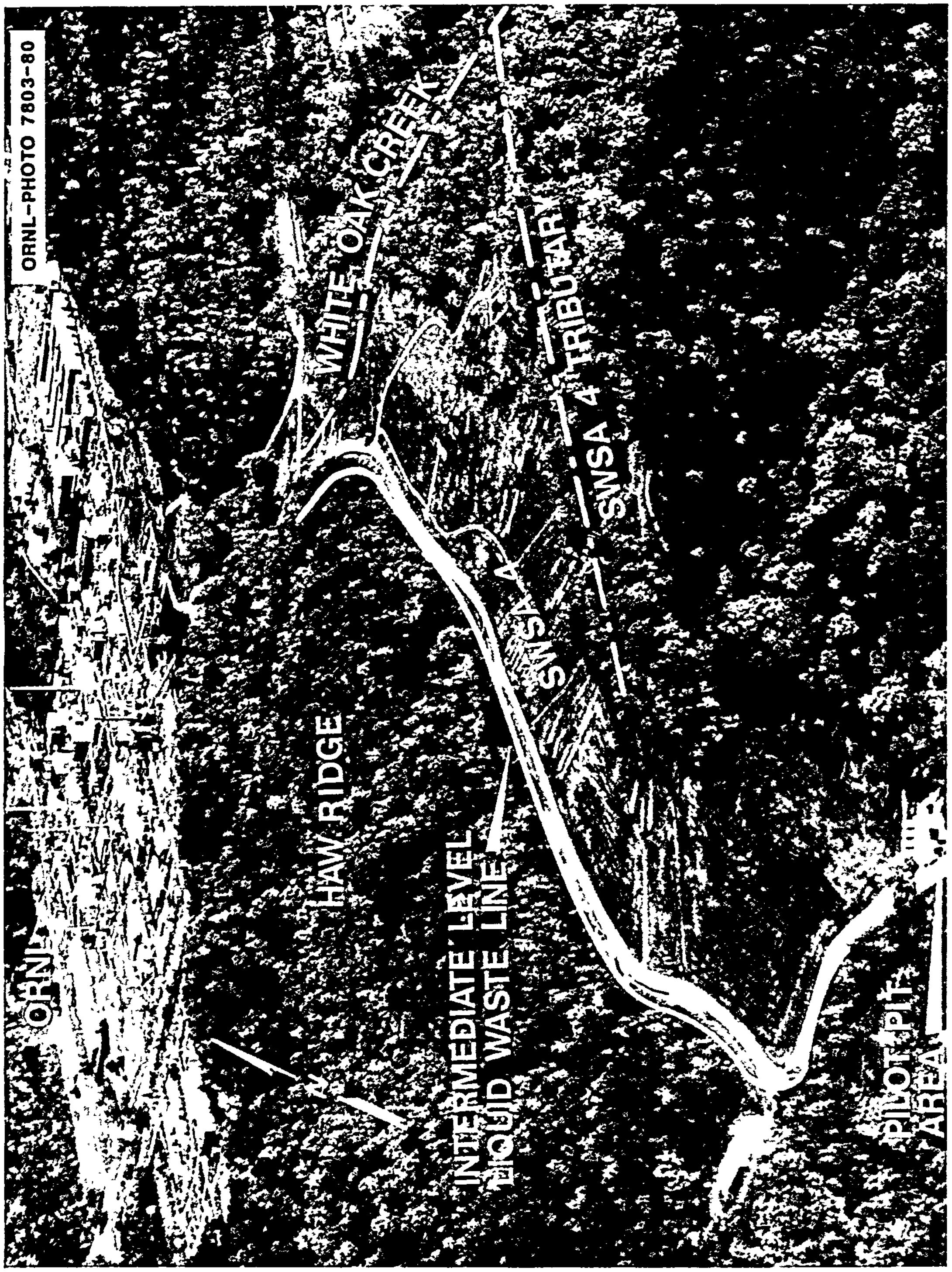

Fig. 1 1980 Aerial view of WAG-4.

2. SITE DESCRIPTION

2.1 History and Purpose of SWSA-4

SWSA-4, previously identified as Burial Ground 4, and its predecessors, Burial Grounds 1, 2, and 3, were developed at ORNL to accommodate various solid radioactive contaminated wastes generated by both defense and research-related nuclear establishments (see Fig. 2 for the location of SWSA-4 within the Oak Ridge Reservation). As the need for waste storage capacity increased at Oak Ridge, the 9.3-ha SWSA-4 site was opened for routine burial in February 1951. The area of this site was approximately twice that of the previous three sites (4.6 ha) in use from 1943 to 1951 (National Research Council 1985).

During the period 1955 to 1963, Oak Ridge was designated by the Atomic Energy Commission as the Southern Regional Burial Ground; as such, this area received a wide variety of poorly characterized wastes from approximately 50 agencies. These solid wastes consisted of paper, clothing, equipment, filters, animal carcasses, and related laboratory wastes; however, exact proportions of each are unknown because records of this nature were not kept. The largest contributors, other than ORNL and the neighboring Y-12 Plant, to the waste volume stored in SWSA-4 during its use (1951-1959) were Argonne National Laboratory, Knolls Atomic Power Laboratory, Mound Laboratory, and the General Electric Company. The waste from these outside sources accounted for approximately 50% of the total buried in SWSA-4.

Wastes were placed in trenches, shallow auger holes, and in piles on the ground surface (to be covered at a later date), as illustrated in Figs. 3 and 4, which are photos taken at the site in 1957. Early records of the amount of waste disposed of at SWSA-4 were destroyed by a fire; however, the volume of waste buried during 1957 and 1958 was approximately 7219 m^3 and 9514 m^3, respectively (Table 1). It is estimated by the ORNL Operations Division that the total waste volume emplaced in SWSA-4 was approximately 5.7×10^4 m^3, consisting of

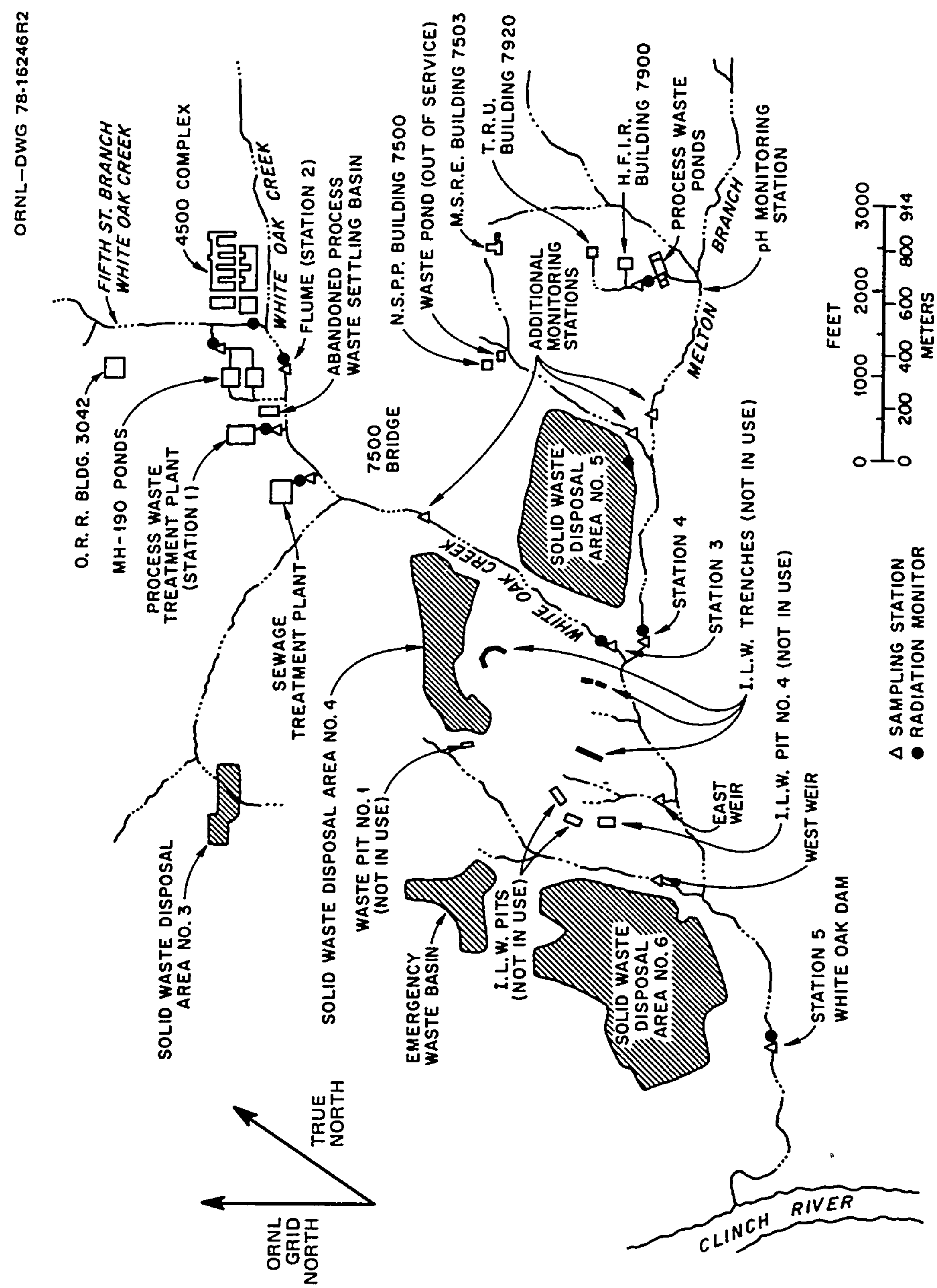

Fig. 2 Location of SWSA-4 within the Oak Ridge Reservation.

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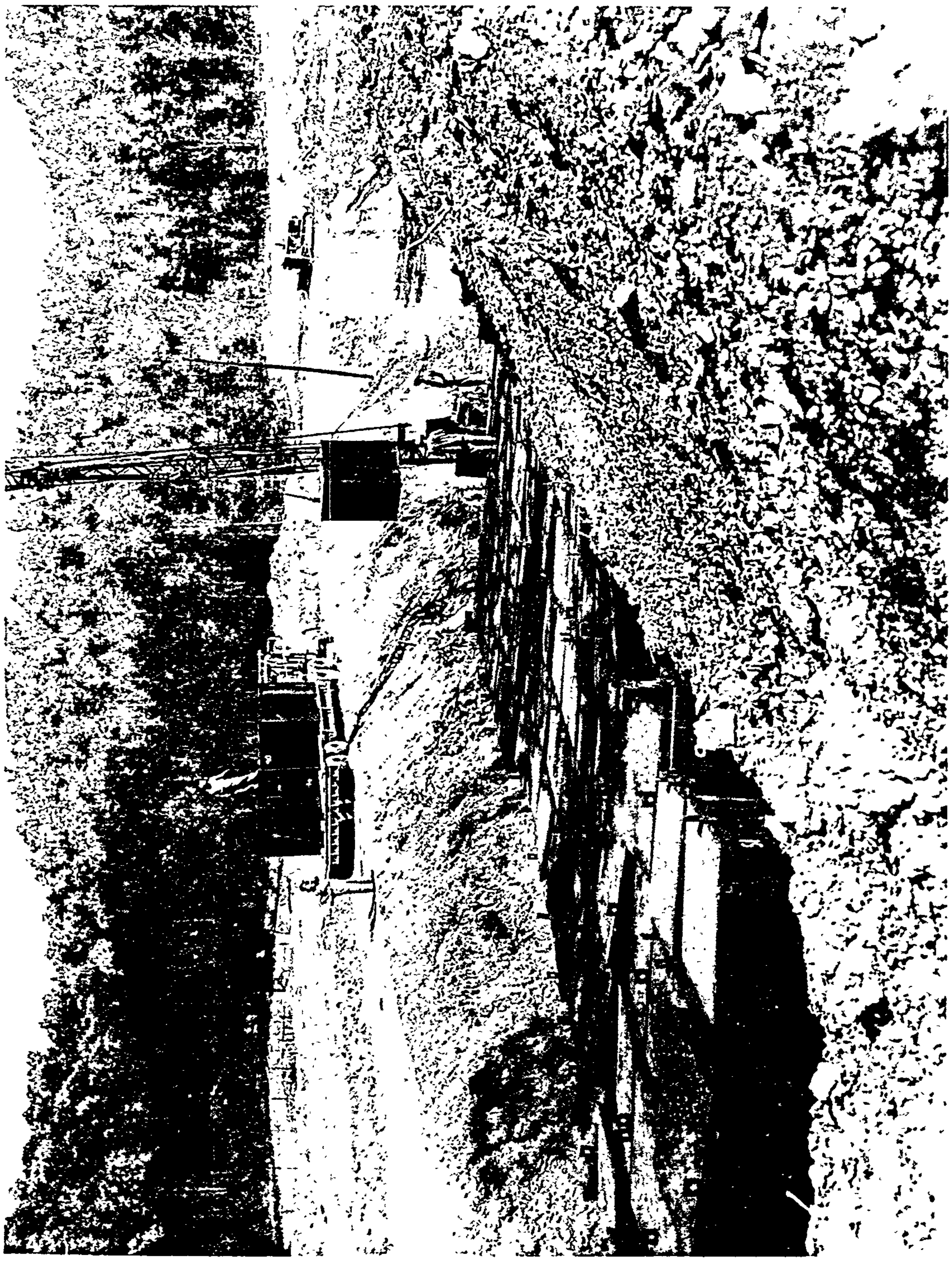

Fig. 3 May 1957 photo showing waste being loaded into a SWSA-4 trench.

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Fig. 4 December 1957 photo showing waste piled in the western portion of SWSA-4.

Table 1. Solid waste burials in SWSA-4 (1957-1958)

Agency	1957 Volume (m^3)	1957 Percentage	1958 Volume (m^3)	1958 Percentage
Local shippers				
ORNL[a]	4021	55.7	4475	47.0
Y-12	283	3.9	425	4.5
UT Agricultural Exp. Station	113	1.6	113	1.2
ORINS[b]	28	0.4	28	0.3
Oak Ridge Processing Co.	170	2.4	453	4.8
Knoxville Iron Co.	113	1.6	311	3.3
K-25	113	1.6		
Off-site shippers				
KAPL[c]	708	9.8	1473	15.5
ANL[d]	821	11.4	963	10.1
GE[e]	198	2.7	538	5.6
Mound Laboratory	396	5.5	311	3.3
Radiological Service Co.	113	1.6	113	1.2
BMI[f]			113	1.2
Others	142	2.0	198	2.1
Totals	7219	100.2	9514	100.1

[a]Oak Ridge National Laboratory.
[b]Oak Ridge Institute of Nuclear Studies.
[c]Knolls Atomic Power Laboratory.
[d]Argonne National Laboratory.
[e]General Electric.
[f]Battelle Memorial Institute.

about 4.1 PBq (1.1×10^5 Ci) of radioactivity. The site was closed to routine burial operations in July 1959 (Lomenick and Cowser 1961); however, it remained open as a disposal area for uncontaminated fill until July 1973.

2.2 History and Purpose of the Intermediate-Activity Low-Level Liquid Waste Transfer Line

Transportation of liquid radioactive wastes from storage tanks at the main ORNL complex to waste pits and trenches in Melton Valley, and later to the hydrofracture site, was accomplished from 1954 to 1975 by pumping wastes through underground transfer lines (Fig 5). The first 2.4-km section of the 5.1-cm-diam cast iron pipe was put into operation in June 1954 to transfer waste to seepage pit 2. This transfer line is on the north side of Lagoon Road and turns south at the extreme west end of SWSA-4 (Fig. 1). The line is buried in weathered Conasauga shale at a depth of about 1 m. Several additions have been made to the line since 1954. In 1960, a 5.1-cm-diam cast iron extension was made to transport waste to trench 5; in 1961, another 5.1-cm diam cast iron line was added to transport waste to trench 6; the line was extended from trench 6 to trench 7 in 1962. When the seepage trench method of disposal was discontinued in 1965, the line was extended to the hydrofracture site where, in December 1966, the first disposal of intermediate-activity low-level waste was completed by this method (Duguid and Sealand 1975).

2.3 History and Purpose of the Experimental Pilot Pit Area

The Pilot Pit Area (Area 7811) was constructed in late 1955 for use in pilot-scale radioactive waste disposal studies on the sintering (fixation) of high-level fuel reprocessing waste into a stable solid (Morgan et al. 1956a; Morgan et al. 1956b; Boegly 1957). The experimental area consists of an asphalt pad surrounded by a 1.8-m chain link fence adjacent to and south of SWSA-4 (Fig. 1). Two

ORNL-PHOTO 0465-71

Fig. 5 A section of the Melton Valley intermediate-level liquid waste transfer line being installed at ORNL in 1971 near the entrance to SWSA 5.

experiments (Pilot Pits 1 and 2) were conducted during 1956-57, only one of which involved radioactivity (approximately 100 mCi of mixed fission products) (Morgan et al. 1958). The ceramic product produced in Pilot Pit 2 contained a tracer level of radioactivity and was removed from the site following its formation. The equipment from Pilot Pit 2 was removed, and the site was being converted for a high-level experiment when the sintering program was terminated by the Atomic Energy Commission.

Currently, three large concrete cylinders imbedded vertically in the ground are on the site. The cylinders contain experimental equipment left when the high-level experiment was terminated (Boegly and Struxness 1959). The only visible feature above the ground, is a control building now used to store various field and laboratory equipment and four large concrete cylinders that were used in a municipal solid waste leaching experiment. Through the years since the site was constructed, the asphalt pad has been used for temporary storage of drill rigs, drums of coal and coal waste products, and other large items used in environmental research.

2.4 Geographic Location and Proximity to White Oak Creek

WAG-4 is located in Melton Valley approximately 0.8 km southwest of the main ORNL plant site (Fig. 1). Haw Ridge runs generally east-west and is located to the north of SWSA-4; Copper Ridge is located to the south. The immediate northern boundary of the site is Lagoon Road; a small tributary to White Oak Creek is near the southern boundary. White Oak Creek is to the east and receives drainage from SWSA-4, which in turn flows to White Oak Lake and ultimately to the Clinch River.

2.5 SWSA-4 Trench and Auger Hole Orientation

Lomenick and Cowser (1961) stated that trenches routinely were excavated in the weathered shale with a backhoe, or if unusually large items were to be buried, a bulldozer or dip bucket was used. Trenches varied considerably in all dimensions, from 15 to 125 m in length, 2.5 to 9 m in width, and 2.5 to 4.5 m in depth. Trench alignment was not consistently in one direction, but was varied throughout the burial ground. One area of longer trenches was toward the middle part of the SWSA; the trenches were arranged northwest-southeast and were oriented on the downslope toward the tributary to White Oak Creek. Other long trenches lie to the northeast of these and were generally arranged in an east-west direction, with the downslope toward White Oak Creek (Fig. 6).

Auger holes, generally 0.3 to 0.6 m in diameter and approximately 4.5 m deep, were located in the northern part of the area along Lagoon Road (Fig. 6). The holes were used to dispose of relatively small packages of higher-activity radioactive waste and also for temporary storage of recoverable materials contaminated with short half-lived fission products.

2.6 SWSA-4 Trench Covers

Trenches within SWSA-4 were originally covered with the excavated soil available from trench construction. Those trenches known to contain alpha-contaminated wastes were covered with an additional 20-cm concrete cap (overlaid by shale) to serve as a marker and intruder barrier (Browder et al. 1959). They are located in the southwest and east-southeast part of the area (Fig. 6) and comprise approximately one-fourth to one-third of the total area; the remainder of the area contains trenches covered with shale. High-activity wastes placed in concrete-covered auger holes make up only a small part of the total SWSA area bordering Lagoon Road.

For several years after the closure of SWSA-4 in 1959, much of the site was used as a construction fill area, and as such, received construction debris such as pipes, concrete blocks, and bricks. This addition of construction debris was estimated to raise the land surface by as much as 6 m in some areas of the site (Lomenick and Cowser 1961; Duguid 1979).

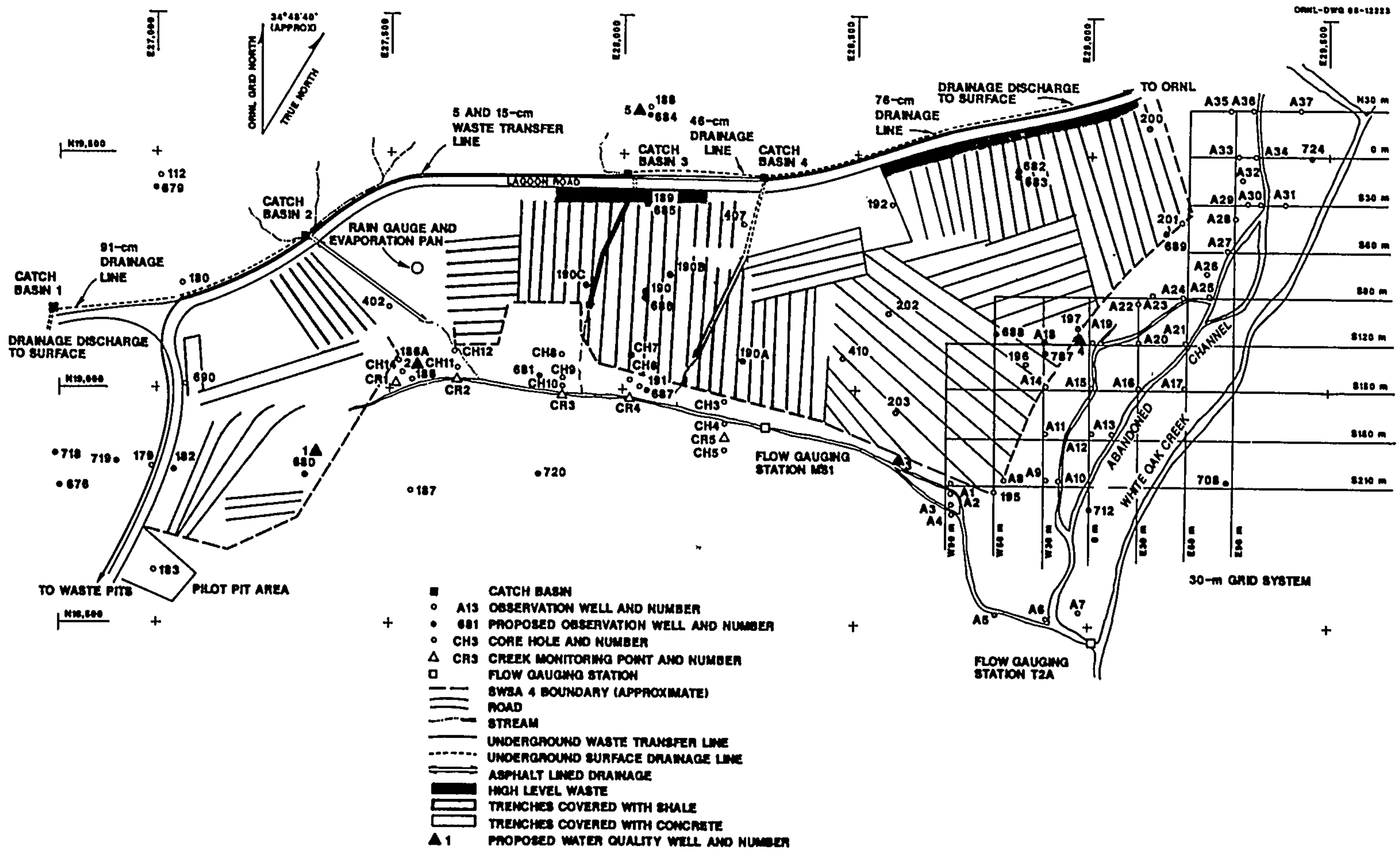

Fig. 6 Map of WAG-4 showing wells, stream gauging stations, and the general location of trenches.

2.7 SWSA-4 Water Diversion Projects

Even at the onset of waste disposal operations in SWSA-4, it was evident that buried waste was contacting water during most of the year. Lomenick and Cowser (1961) reported that burial was limited to higher elevations within the burial ground during the wet winter months, whereas the low topography was used during the dry summer months. This problem with water stemmed from the fact that SWSA-4 was located in a low topographic area, essentially parallel to a small tributary that drained the south side of Haw Ridge and entered White Oak Creek. Had present-day standards been applied to the site selection process, the present area would probably have been rejected in favor of a site in Melton Valley containing significantly higher ground.

Some of the water-related problems that were noted during early site operation include a minimum depth to water of between 0.6 and 1.0 m in the low areas, radioactivity detected in a number of the site monitoring wells, and the appearance of four distinct trench seeps that were found to contain a number of different radionuclides (^{106}Ru, ^{60}Co, ^{137}Cs, ^{90}Sr, ^{95}Zr-^{95}Nb, $^{239-240}$Pu, ^{210}Po, and the rare earths). The early recognition of these problems has spawned a number of field-scale investigations of the SWSA-4 hydrology (Huff, Farrow, and Jones 1982; Stueber et al. 1981; Tamura et al. 1980; Melroy and Huff 1985), all of which point to the importance of a 14-ha upslope area (draining the south side of Haw Ridge) as a contributing factor to SWSA-4 water problems.

During the 27 years since routine burials have ceased, two major engineering remedial actions were taken at SWSA-4 in an attempt to isolate the burial trenches from this upslope recharge area. The first of these projects was initiated in 1975 and consisted of constructing a bituminous concrete drainage ditch along the northern boundary of the site to catch surface runoff from Haw Ridge and direct it under Lagoon Road to one of three similarly lined ditches that crossed SWSA-4 and emptied into the small tributary to the south. A detailed summary of this engineered remedial action is contained in ORNL Engineering

Drawings 20917 EA 001 through 20917 EA 007. It was thought that this lining of the natural drainage ditches would transport runoff across SWSA-4 and into the White Oak Creek tributary before a significant amount of groundwater recharge could take place through the runoff and stream channels. Subsequent studies evaluating the effectiveness of this drainage project (Tamura et al. 1980) have shown that no reduction has taken place in the radionuclide discharges to White Oak Creek originating from SWSA-4. It was speculated that the lined ditches that ran across the area were not extended far enough toward the tributary and may actually have discharged into the southern end of some waste disposal trenches, or at the edge of a contaminant plume that had already formed between the disposal site and the tributary. In retrospect, this first attempt at routing runoff across SWSA-4 may have been more successful if, in addition to the three drainage paths that traversed the area, the upper reaches of the tributary had been lined also.

The second water diversion project at SWSA-4 was initiated in 1983 and consisted of routing drainage from Haw Ridge around the area rather than over it. In this respect, it was actually a modification to the existing drainage system. The design called for three components to the system: (1) a paved interceptor channel north of Lagoon road, (2) four catch basins that receive runoff from the interceptor channel and from the natural channels draining Haw Ridge, and (3) an underground storm drain system that diverts runoff around the disposal site to both the east and west (Fig. 7). The existing culverts under Lagoon Road were sealed so that all runoff originating north of SWSA-4 was diverted to White Oak Creek. A summary of the engineered remedial action is contained in ORNL Engineering Drawings 20917 A012 through 20917 A015. These drawings also show the location of the intermediate-activity low-level liquid waste transfer line in relation to Lagoon Road.

The storm drain system shown as a heavy dashed line in Fig. 7 was constructed in two sections: a 183-m western section with a maximum

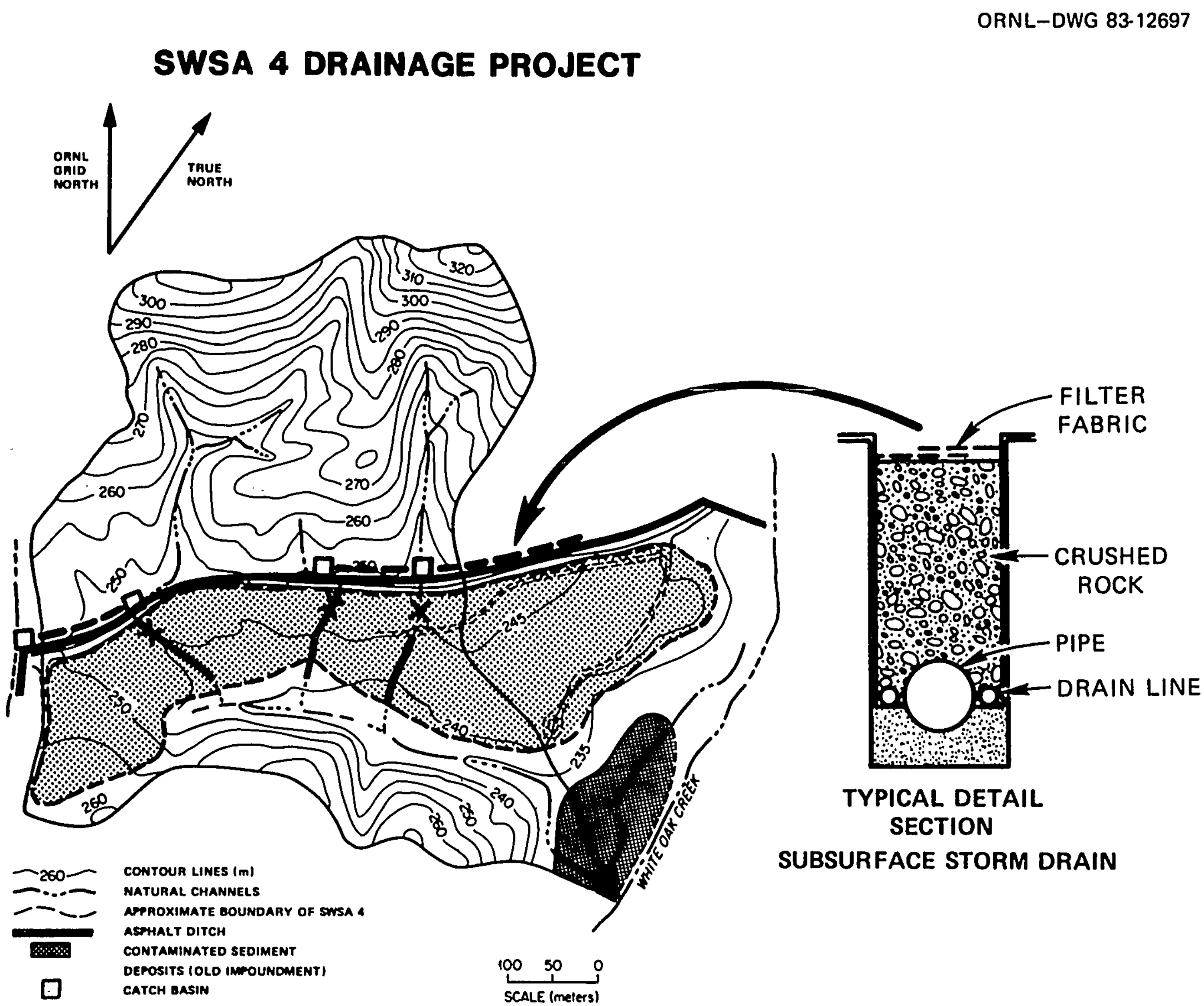

Fig. 7 Plan view of the 1983 SWSA-4 surface water diversion project.

depth of 6.4 m and a 293-m eastern section with a maximum depth of 4 m. Both sections of drain were designed with a bottom slope of approximately 1%. At the same time the storm drain pipe was being placed in the excavation, two smaller perforated pipes were installed on the trench bottom, and the excavation was backfilled with crushed stone. The perforated pipes and crushed stone served to drain off any shallow subsurface flow entering the excavation that might otherwise flow southward under Lagoon Road and into the waste trenches.

At the completion of the drainage project, flow measurements and stream samplings of the SWSA-4 tributary were continued as part of the project evaluation. It was concluded that the quantity of ^{90}Sr (the radioisotope of primary concern) entering White Oak Creek was significantly reduced, with an estimated flux reduction of 46% during the initial 6 months of monitoring (Melroy and Huff 1985, Davis et al. 1985). By reducing the area of the contributing watershed by 56%, an equal flow reduction in the SWSA-4 tributary was observed. This translates to 56% less flow in the contaminated reaches of the tributary and thus a reduction in ^{90}Sr discharge.

Evaluations of the water diversion projects described in this section have been significant contributions to knowledge of the environmental problems associated with SWSA-4. To a large extent, they have served as the impetus for initiating hydrologic monitoring that will be an integral part of future RCRA-related site monitoring plans. As an example, precipitation, stream flow, and groundwater monitoring have all been required as components of the evaluations that have taken place. In addition, the detection of surface water seeps from trenches has led to a detailed study of contamination throughout SWSA-4 (Melroy, Huff, and Farrow 1986) and the relationship of these seeps to trenches that are periodically filled with water. Thus, the background information and monitoring needs being developed in this report will build on existing knowledge of the site and provide the information necessary to make decisions about future remedial actions.

3. CURRENT STATUS OF SITE INFORMATION

3.1 Radionuclide and/or Hazardous Waste Inventory

During the period of SWSA-4 operation (1951-1959), records were kept of the volume and the estimated total activity of waste. A fire in Building 7803, which was located at the entrance to SWSA-5, reportedly destroyed all records except for the latter two years (Table 1 and Fig. 8). In spite of the missing records, the total volume of waste is estimated to be 5.7×10^4 m^3, and the total radioactivity when emplaced was approximately 4.1 PBq (1.1×10^5 Ci). Because of the loss of records, specific amounts of radionuclides emplaced in SWSA-4 are not known; however, in addition to the wastes received from other facilities, ORNL historically has had a number of programs generating ^{239}Pu, ^{140}Ba-^{140}La, ^{90}Sr, ^{137}Cs, $^{242-244}Cm$, ^{3}H, ^{60}Co, ^{85}Kr, ^{241}Am, and U-Th fuels. In addition, radioisotope application development for medical and industrial uses was a major program during the time SWSA-4 was in operation. Without accurate records, it must be assumed that the area received a mixture of transuranic, hazardous, and radioactive wastes. The monitoring plan developed for SWSA-4 must reflect this assumption and focus on detecting a wide range of potential contaminants from throughout the site.

3.2 Geology and Soils

Melton Valley is underlain by the Conasauga shale of Cambrian age (Fig. 9). The shale is about 450 m thick, with the most common angle of dip being 30° to 40° to the southeast. However, because of the incompetent nature of the formation, considerable variations in dip occur. The structural strike of the strata is reported to vary from north 45° east to north 60° east (Stockdale 1951). The basal part of the Conasauga (Pumpkin Valley shale) consists mostly of red shale which grades upward into gray calcareous shale containing thin lenticular beds of limestone. The amount of limestone increases toward

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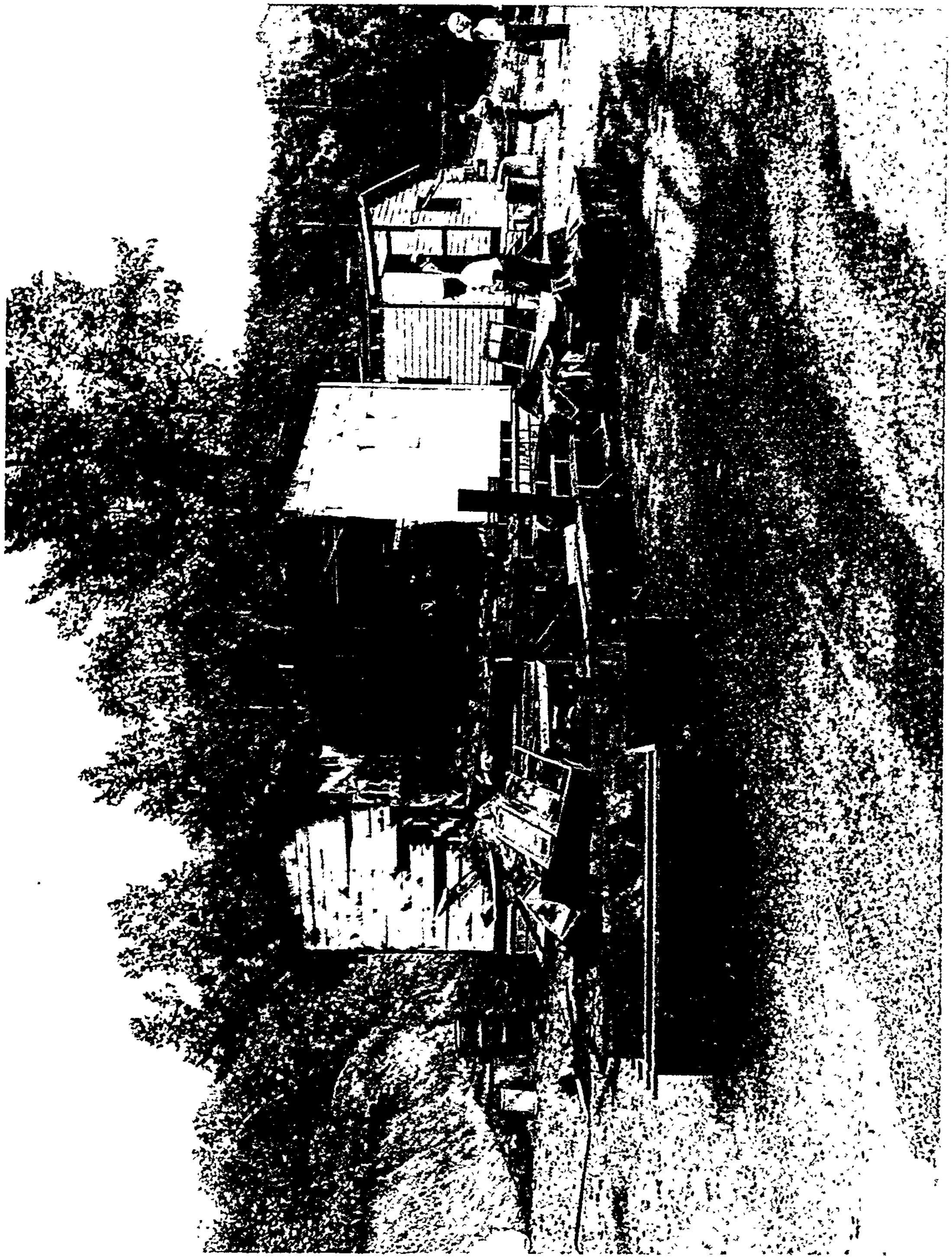


Fig. 8 Fire damage to ORNL Building 7803 that housed the SWSA-4 records.

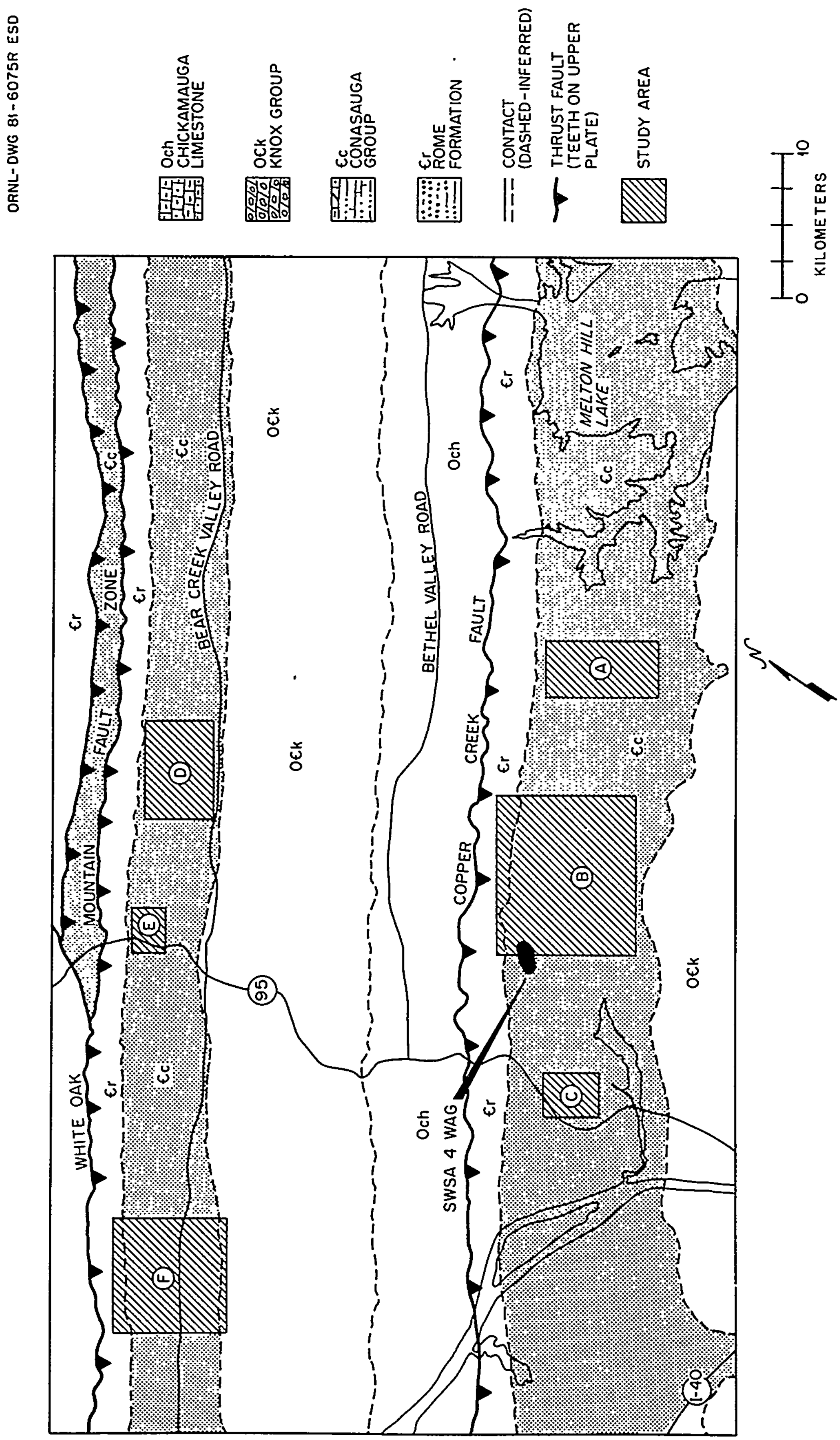


Fig. 9 Geologic map of the Oak Ridge Reservation.

the southeast and is predominant in the uppermost portion of the formation. Silty beds occur throughout the formation, but are most numerous in the lower half. These resistant siltstones account for the line of low hills, or knolls, which rise above the valley floor along the northwest side.

SWSA-4 is situated just northwest of a low hill (underlain by siltstone) in the lower part of the Conasauga, where a transition zone exists between the basal red shales and the overlying gray shales and interbedded lenticular limestones. The formation here consists mostly of dark, maroon-to-brown, noncalcareous shales, interbedded with gray, slightly calcareous shales, and thin gray-blue, silty limestones. A few discontinuous, relatively pure, thin limestone lenses are present, along with an occasional fine-grained, green, siltstone bed. Red and brown shales predominate in the northwest part of the area; however, in the southeast portion, grey shales and interbedded silty limestones are most prevalent. The shales usually weather to a dull olive, yellow, or brown color, and the silty limestones weather to resistant siltstone lenses. The weathered siltstones and the shales have well-developed joints that are open near the surface. Joint surfaces are frequently stained reddish brown to black. In the higher elevations of the burial ground, weathered material extends down 4 to 5 m; whereas, in the lower elevations, fresh rock is encountered within 1 to 1.5 m of the surface. A few meters of yellow-to-red, clayey soil was observed over some parts of the area, but did not persist vertically or laterally.

Dip measurements made in and around the burial ground range from vertical to 27° southwest. Strike measurements varied from north 85° east to north 15° east. The wide range in dip and strike indicates that many small structures are present within the site (Lomenick and Cowser 1961).

3.3 Hydrology

A considerable amount of hydrologic data have been collected at SWSA-4 as a result of evaluating two previously constructed surface water diversion projects. These data include site precipitation, flow in the SWSA-4 tributary to White Oak Creek, seasonal fluctuations in the water table, and periodic water quality monitoring at selected wells and surface streams.

3.3.1 Precipitation

A single rain gauge (Fischer and Porter 7.5 V punch tape type) located at the SWSA-4 site since December 1984 has been monitoring site precipitation at 5-min intervals. The tapes removed from the gauge have been translated (Stevens Translator), and the 5-min interval data have been stored on magnetic disks. The data sets have also been run through a breakpoint program to strip them of unnecessary records; however, the breakpointed data have not been further processed to construct monthly summaries.

A second rain gauge (Model 9432 Belfort Instrument Company 30-cm dual traverse weighing bucket) located in SWSA-6 at the Engineered Test Facility (ETF) has been in operation since August 11, 1980 (Davis et al. 1984). Data collected at the ETF site are applicable to SWSA-4 because of the close proximity and the fact that most precipitation events are sufficiently widespread to encompass both sites. Table 2 summarizes the monthly totals collected at the ETF gauge, along with the record mean for the Oak Ridge area from 1948 to 1981.

3.3.2 Flow in the SWSA-4 Tributary

Two surface water discharge monitoring stations have been established on the SWSA-4 tributary at the locations shown in Fig. 6. The upstream station (MS1) has flow data available from April 1983 through December 1985. The downstream station (T2A), located at the point where the SWSA-4 tributary empties into White Oak Creek, has flow data and ^{90}Sr flux data available from October 1983 to December 1985. Table 3 summarizes the monthly flow volumes for the two stations based on this 2 1/2-year period of record. In addition to flow, Table 3 contains ^{90}Sr data for station T2A. These data were

Table 2. Summary of SWSA-6 and Oak Ridge rainfall data

Month	SWSA-6 site (mm)	Oak Ridge site[a] (mm)
1980		
August	32.5[b]	96.3
September	68.7	92.2
October	46.3	74.9
November	101.6	116.1
December	43.5	141.0
Total	292.6	520.5
1981		
January	22.1	137.4
February	119.3	120.6
March	73.4	153.9
April	93.7	109.0
May	108.5	106.4
June	122.3	105.2
July	74.0	135.1
August	75.5	96.3
September	71.0	92.2
October	93.5	74.9
November	79.2	116.1
December	102.4	141.0
Total	1034.9	1388.1
1982		
January	162.8	137.4
February	130.9	120.6
March	162.6	153.9
April	64.4	109.0
May	60.7	106.4
June	70.4	105.2
July	138.0	135.1
August	92.4	96.3
September	63.6	92.2
October	61.4	74.9
November	150.8	116.1
December	177.3	141.0
Total	1335.3	1388.1

Table 2. (Continued)

Month	SWSA-6 site (mm)	Oak Ridge site[a] (mm)
1983		
January	39.3	137.4
February	103.3	120.6
March	54.1	153.9
April	114.3	109.0
May	132.1	106.4
June	53.9	105.2
July	48.0	135.1
August	29.2	96.3
September	44.8	92.2
October	116.4	74.9
November	137.3	116.1
December	184.8	141.0
Total	1057.5	1388.1
1984		
January	61.3	137.4
February	92.2	120.6
March	113.3	153.9
April	95.4	109.0
May	272.1	106.4
June	91.8	105.2
July	180.6	135.1
August	43.2	96.3
September	20.3	92.2
October	156.2	74.9
November	113.0	116.1
December	52.7	141.0
Total	1292.1	1388.1
1985		
January	56.5	137.4
February	79.4	120.6
March	36.8	153.9
April	43.2	109.0
May	59.7	106.4
June	132.7	105.2
July	100.9	135.1
August	230.5	96.3
September	42.5	92.2
October	75.6	74.9
November	101.6	116.1
December	52.7	141.0
Total	1012.0	1388.1

Table 2. (Continued)

Month	SWSA-6 site (mm)	Oak Ridge site[a] (mm)
1986		
January	31.1	137.4
February	103.5	120.6
March	71.7	153.9
April	51.4	109.0
May	76.8	106.4
Total	334.5	627.3

[a]Mean value taken from data collected at the Oak Ridge site for the period 1948 to 1981.

[b]Rainfall gauging station was not in operation until August 10, 1980.

Table 3. Monthly flow summaries for two gauging stations located on the SWSA-4 tributary

Month	Station MS1 (m^3)	Station T2A (m^3)	^{90}Sr Flux at T2A (mCi)
1983			
May	13,446	a	a
June	1,244	a	a
July	201	a	a
August	16	a	a
September	1.2	a	a
October	398	197[b]	1.46[b]
November	4,397	3,240	21.15
December	9,628	11,219	70.03
Total	29,331.2	14,656	92.64
1984			
January	5,074	5,794	44.00
February	5,430	5,079	34.70
March	6,825	8,711	54.30
April	4,857	6,069	43.22
May	13,237	27,974	81.84
June	459	1,016	8.08
July	3,362	4,040	26.36
August	1,679	1,553	7.31
September	188	806	6.63
October	2,925	3,029	14.34
November	4,512	5,561	38.36
December	3,524	3,195	26.83
Total	52,072	72,827	385.97
1985			
January	3,375	3,147	25.39
February	8,495	7,741	54.29
March	3,532	4,282	35.04
April	2,864	2,551	20.72
May	658	385	3.33
June	430	516	4.10
July	564	331	2.78
August	4,925	7,622	26.49
September	942	781	6.75
October	1,016	840	7.21
November	4,640	4,756	32.04
December	4,223	3,731	27.38
Total	35,664	36,683	245.52

[a] Station not in operation.
[b] Flow data for October 20 through October 31 only.

generated from a relationship between flow and ^{90}Sr concentration developed earlier by Huff et al. (1982).

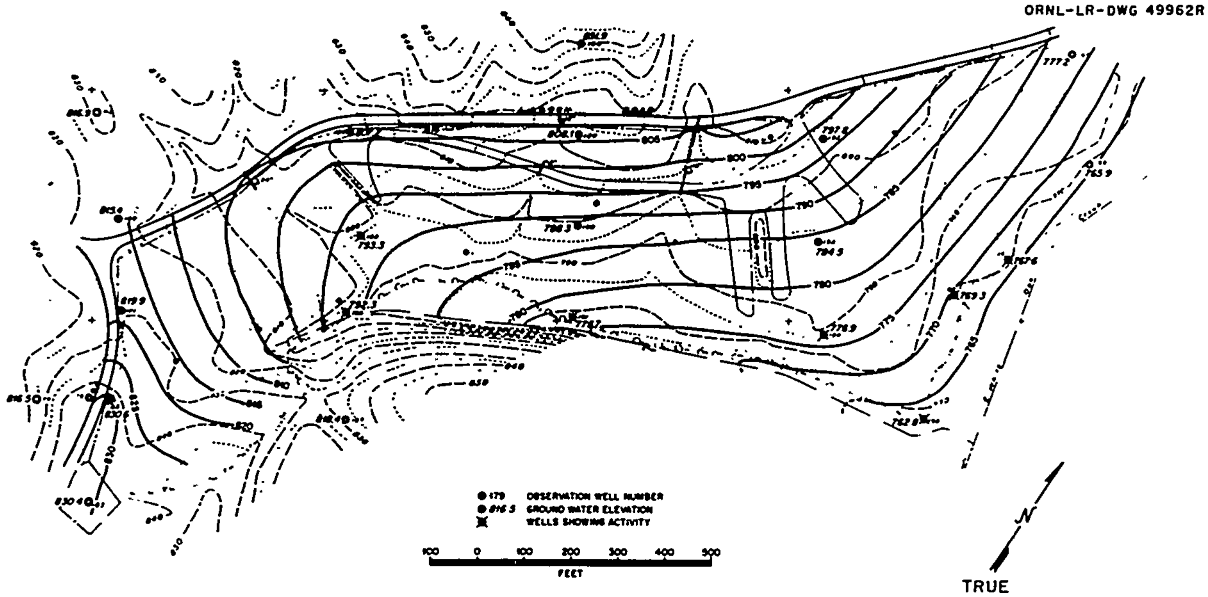
Additional flow measurements have been made at SWSA-4 as part of the evaluation of the surface water diversion project that was completed in 1983. A complete discussion of these data, along with the locations and dates of the flow measurements, is contained in Melroy and Huff (1985).

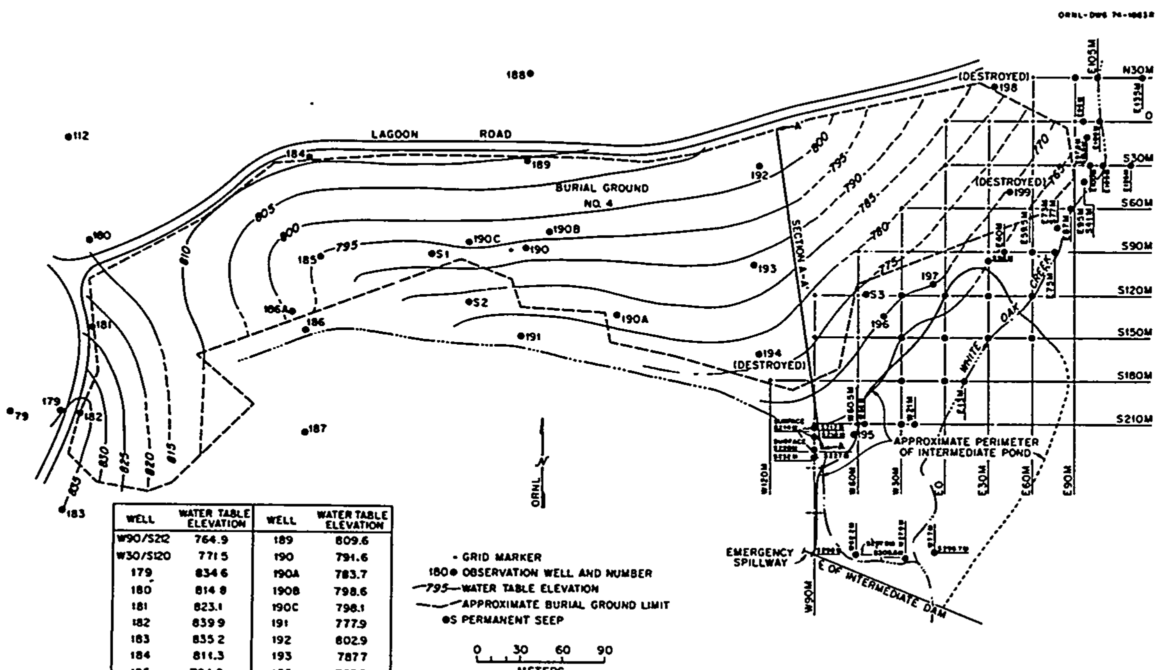
3.3.3 Water Table Fluctuations

Since SWSA-4 began operations in 1951, approximately 85 wells have been drilled on the site to collect water samples and measure water table elevations. For the 5-year period spanning 1975 to 1979, the U.S. Geological Survey (USGS) has published water level data for 32 of these wells (Webster et al. 1981). Since publication of this first water level data document, the USGS has conducted a number of tests in SWSA-4 wells yielding important hydraulic data pertaining to the Conasauga Formation (Webster and Bradley, in press).

In addition to the data collected by the USGS, ORNL has been collecting water level data at 11 core hole locations and 5 points along the SWSA-4 tributary. The core hole locations were established as part of the ground surface contamination study described in Sect. 3.4 and consist of holes that have been cased with PVC pipe open at the bottom to function as a shallow piezometer. Water level data for these 11 shallow piezometers and the 5 tributary locations are available for June 1983 through December 1985; a portion of the data set is included as Appendix B.

From water table data available for SWSA-4, two water table maps have been prepared by Lomenick and Cowser (1961) and Duguid (1975) and are included as Fig. 10. Both maps indicate that the high water table (253 m or 830 ft) exists in the southwest corner of the site, and the low table (233 m or 765 ft) is in the southeast corner. The general direction of flow is toward the southeast and the SWSA-4 tributary.





WELL	WATER TABLE ELEVATION	WELL	WATER TABLE ELEVATION
W90/S212	764.9	189	809.6
W30/S120	771.5	190	791.6
179	834.6	190A	783.7
180	814.8	190B	798.6
181	823.1	190C	798.1
182	839.9	191	777.9
183	835.2	192	802.9
184	811.3	193	787.7
185	794.0	195	763.3
186	792.4	196	770.1
186A	799.3	197	771.0

Fig. 10 Water table map of SWSA-4. Top: December 24, 1959, bottom: February 1, 1974.

3.3.4 Water Quality

The earliest water quality data for SWSA-4 were reported by Lomenick and Cowser (1961); the results of radiochemical and chemical analyses from wells sampled during a 5-month period in 1959 and 1960 were given. Seeps from burial trenches and samples from both upstream and downstream of White Oak Creek were also taken. Samples from wells in SWSA-5 prior to burial activities in that area were used as controls.

Gross alpha and beta activities and specific radionuclides such as ^{90}Sr, ^{106}Ru, and total rare earths (TRE) were analyzed for some samples. Anions and cations that indicated leaching from certain trenches included calcium, sodium, nitrate, chloride, and sulfate. Total hardness as calcium carbonate was also reported. Summaries of the data are included in Tables 4, 5, and 6. Well numbers refer to those in Fig. 6.

From an analysis of Table 4, it is apparent that many of the wells, as well as the seeps and stream, contain elevated concentrations of anions and cations usually associated with metal degradation at waste disposal sites. The principal radionuclides detected were ^{137}Cs and ^{90}Sr; however, later samplings by Duguid also show that elevated levels of tritium are present.

Duguid (1975) reported on the status of radioactivity movement in SWSA-4. Concentrations of ^{90}Sr, ^{60}Co, ^{137}Cs, ^{125}Sb, and ^{3}H were reported for older wells and three of the four identified surface seeps (Table 7). In addition, Duguid divided SWSA-4 into an eastern and western region and reported ^{90}Sr concentrations on selected sampling dates (Table 8).

Duguid concluded that ^{90}Sr was of particular concern in SWSA-4 and that the concentration found in the groundwater along the east side of the site (average = 114 Bq/L) was lower than the concentration found along the west side (average = 221 Bq/L). He further estimated that between 4.4×10^{10} and 1.8×10^{11} Bq (1.2 and 4.8 Ci) of ^{90}Sr per year were discharged from SWSA-4 between 1963 and 1973, and that approximately one-third of the annual release of ^{90}Sr to the Clinch River in that period originates from SWSA-4. Thus, although an exact

Table 4. Chemical analysis of water from auger wells, seeps, and streams in SWSA-4 and noncontaminated auger wells in SWSA-5 reported by Lomenick and Cowser (1961)

Well Nos.	Ca^{2+} (mg/L)	Na^{+} (mg/L)	NO_3^- (mg/L)	Cl^- (mg/L)	$SO_4^{=2}$ (mg/L)	Total Hardness (mg/L) as $CaCO_3$
			Contaminated wells in SWSA 4			
182	50	92	24	74	800	749
191	30	34	20	32	71	211
194	394	58	88	674	780	1420
196	40	56	19	59	143	295
197	67	56	29	87	163	270
Seep 2[a]	26	72	32	78	78	194
Stream	25	41	35	39	51	147
			Noncontaminated wells in SWSA-5[b]			
Four Well composite sample	68	2.1	1.2	1.3	8.7	193

[a]Located along eastern boundary of SWSA-4 near White Oak Creek.
[b]Samples at SWSA-5 taken prior to burial.

Table 5. Summary of radioactivity in SWSA-4 wells reported by Lomenick and Cowser (1961)

Well No.	No. of samples taken 8/17/59 to 1/22/60	Gross β activity[a] (cpm/mL)			Radionuclides in composite sample (dpm/mL)		
		Max	Min	Mean	^{90}Sr	TRE[b]	^{106}Ru
182	21	12	3.4	8	25	39	4
185[cd]	21	3.8	0	1			
186[d]	21	20	0	2.4			
191	21	16	4.2	7	22	33	3
194	20	14	0	5.8	32	48	0
195[d]	19	8	0	1.3			
196	20	31	4.4	12	56	83	<1
197	21	12	0	4.2	24	36	0

[a]Gross beta counted at approximately 8% geometry.

[b]Total rare earths counted at 22.3% geometry.

[c]Gross alpha counted at approximately 47% geometry.

[d]Not analyzed for specific nuclides.

Table 6. Summary of radioactivity detected in SWSA-4 seeps and streams reported by Lomenick and Cowser (1961)

	No. of Samples Taken	Gross activity[a] (cpm/mL)					
		Max		Min		Mean	
		Gross β	Gross α	Gross β	Gross α	Gross β	Gross α
Seep 1	15	18	0.3	3.2	.0	8	0.1
Seep 2	17	85	6.5	4.9	.0	17	1.1
Seep 3	8	370	140	3.8	.0	160	18
Seep 4[b]	4	520	320	37	1.9	170	23
Stream	17	23	100	4.3	.1	12	23

	Radionuclides in composite sample (dpm/mL)							
	^{137}Cs	^{60}Co	^{90}Sr	^{95}Zr/Nb	^{106}Ru	TRE[c]	^{210}Pb	$^{239/240}$Pu
Seep 2			85			130		
Seep 4[b]	130	14	290	Trace		330		
Stream			42		2	60	Trace	Trace

[a]Gross beta counted at approximately 8% geometry; gross alpha counted at approximately 47% geometry.

[b]Specific radionuclides from sample dated April 1, 1960 (alpha identification uncertain because of excess solids in samples).

[c]Total rare earths counted at 22.3% geometry.

Table 7. Radionuclide concentrations (Bq/L) in SWSA-4 old wells reported by Duguid (1975, 1976).

Well	Date	^{90}Sr	^{60}Co	^{137}Cs	^{125}Sb	^{3}H
179	8-27-73	$\leq$1.7	$\leq$0.30	1.35	$\leq$0.50	a
182	8-27-73	5.0	$\leq$0.30	$\leq$0.33	$\leq$0.32	a
	9-23-74	8.5	a	a	a	a
185	8-27-73	270	$\leq$0.37	$\leq$0.32	$\leq$1.1	a
	9-23-74	263	3.3	a	a	19,980
186	10-05-73	142	$\leq$0.43	$\leq$0.22	$\leq$0.82	a
	9-23-74	122	1.67	a	a	8,510
187	8-27-73	96.7	26.6	$\leq$18.3	$\leq$15	a
	10-05-73	$\leq$1.0	$\leq$0.27	$\leq$0.25	$\leq$0.28	a
188	10-05-73	$\leq$0.82	$\leq$0.43	$\leq$0.40	$\leq$0.35	a
189	8-27-73	1.7	$\leq$0.30	$\leq$0.27	$\leq$0.27	a
190	8-27-73	483	$\leq$0.32	$\leq$0.28	$\leq$0.93	a
	9-23-74	740	a	a	1.7	4,810
190A	8-27-73	590	$\leq$0.32	2.8	1.8	a
	9-23-74	629	a	a	1.7	a
190B	8-27-73	150	$\leq$0.57	$\leq$0.40	$\leq$0.55	a
	9-23-74	126	a	a	a	9,990
190C	9-23-74	263	a	a	a	a
191	8-27-73	1,340	$\leq$0.65	$\leq$0.57	1.6	a
	9-23-74	1,150	a	a	1.7	4,440
192	8-27-73	10.0	$\leq$0.28	$\leq$0.53	$\leq$0.33	a
	9-23-74	8.5	a	a	a	a
193	8-27-73	3.3	$\leq$0.28	$\leq$0.32	$\leq$0.22	a
	9-23-74	6.7	a	a	a	a
Seep 1	1-23-74	18.3	$\leq$0.43	$\leq$0.22	$\leq$0.23	a
Seep 2	8-27-73	7,520	$\leq$1.7	90.3	16.7	a
	1-23-74	2,900	1.6	$\leq$0.33	$\leq$0.35	a
Seep 3	3-19-73	232	3.3	$\leq$3.3	$\leq$3.3	a

[a]Analysis not performed.

Table 8. Concentration of ^{90}Sr (Bq/L) measured in water in eastern and western region of SWSA-4 by Duguid (1975, 1976).

	Western portion of SWSA-4				
Well	12-12-73	1-23-74	9-11-74	4-7-75	Average
S212/W90	132	133	218	122	151
S214/W90	292	337	444	a	358
S218/W90	257	263	370	174	266
S227/W90	270	225	289	240	256
S228/W90	280	320	196	a	265
S232/W90	38.3	26.7	44.4	20.0	32.3

Average = 221

	Eastern portion of SWSA-4					
	8-7-73	10-5-73	1-23-74	9-11-74	4-7-75	Average
30/E90	3.3	a	a	0.0	3.3	3.3
N30/E105	21.7	31.7	33.3	16.6	21.5	25.0
N30/E135	a	21.7	76.7	115	66.6	70.0
N0/E95	a	3.3	1.7	11.1	6.7	5.7
N0/E106	20.0	21.7	1.7	23.3	11.5	15.6
S6.6/E97.8	a	30.0	41.7	31.4	20.0	30.8
S30/E100	a	115	50.0	44.4	25.2	58.6
S30/E109	173	142	140	274	66.6	159
S30/E125	a	5.0	145	226	159	134
S41/E95	a	a	168	133	104	135
S60/E87	38.3	86.7	26.7	40.7	107	59.9
S77/E73	a	192	450	355	322	330
S90/E40	a	235	18.3	16.6	5.2	68.8
S90/E60	113	65.0	140	159	85.1	112
S90/E75	58.3	78.3	33.3	33.3	62.9	53.2
S96/E30	a	66.7	95.0	133	85.1	94.9

Table 8. (Continued)

	Eastern portion of SWSA-4					
	8-7-73	10-5-73	1-23-74	9-11-74	4-7-75	Average
197	46.7	71.7	25.0	26.6	23.3	38.7
NS120/W30	143	a	3.3	1.7	3.3	37.8
S120E0	167	105	120	170	92.5	131
S120/E30	91.7	90.0	50.0	99.9	31.4	72.6
S120/E60	127	a	193	115	200	159
196	a	607	475	518	337	484
S150/W30	263	193	263	266	203	238
S150/E0	250	46.7	10.0	48.1	44.4	79.8
S150/E30	192	73.3	132	229	207	167
S150/E60	a	85.0	25.0	21.5	185	79.1
S180/W30	245	162	207	252	170	207
S180/E0	30.0	48.3	35.0	23.3	44.4	36.2
S210/W56	a	203	208	141	148	175
S210/W30	302	233	210	259	152	231
S210/W21	195	110	168	185	104	152
195	a	a	a	92.5	118	105
S295.7/W7.7	a	a	a	92.5	24.8	58.6
S297.9/W62.2	a	a	a	166	133	149
S300.6/W27.9	a	a	a	30.0	118	74.0
						Average = 114

[a]Sample not taken on this date.

waste inventory is not available, previous research has pointed to the specific radionuclides of concern in SWSA-4 and the ones that must be considered in investigating migration pathways.

3.4 Surface Contamination Investigations

Work by Stueber (1981) has confirmed earlier studies by Duguid that showed that SWSA-4 is a major contributor of ^{90}Sr to White Oak Creek (via the SWSA-4 tributary), and that a number of contaminated surface seeps appear along the southern boundary of the site, particularly during the wet months of the year. This observation is consistent with earlier reports by Lomenick and Cowser (1961) that these lower elevation areas could not be used for disposal trenches during wet months.

Spalding and Munro (1984) conducted a survey of ^{90}Sr in SWSA-4 groundwater by sampling approximately 129 locations along a 720-m perimeter transect to the south and east of the area (Fig. 11). Shallow groundwater samples were collected and filtered, and ^{90}Sr was determined by Cerenkov radiation counting (Larsen 1981). Several "peaks" of ^{90}Sr occurred along the transect (Fig. 12) and were located in the general vicinity of seeps previously identified by Duguid. Conclusions were that the ^{90}Sr concentrations on the entire eastern side of SWSA-4 (i.e., 390 to 720 m along the transect) were quite small in comparison with the 0- to 200-m reach of the southern perimeter. This observation supports past conclusions that this southern area should be the focus of study for any proposed corrective actions in SWSA-4.

To further map these contaminated seeps and quantify the local soil contamination that resulted, Melroy et al. (1986) surveyed the southern portion of SWSA-4 using a Geiger-Muller survey meter and the 30-m grid previously established at the site. Figure 13 summarizes the results of this survey by presenting gross counts/min contours across the site. Several areas of surface contamination were identified in this study, and the locations of soil sampling stations and soil coring stations were established for further investigation of surface contamination.

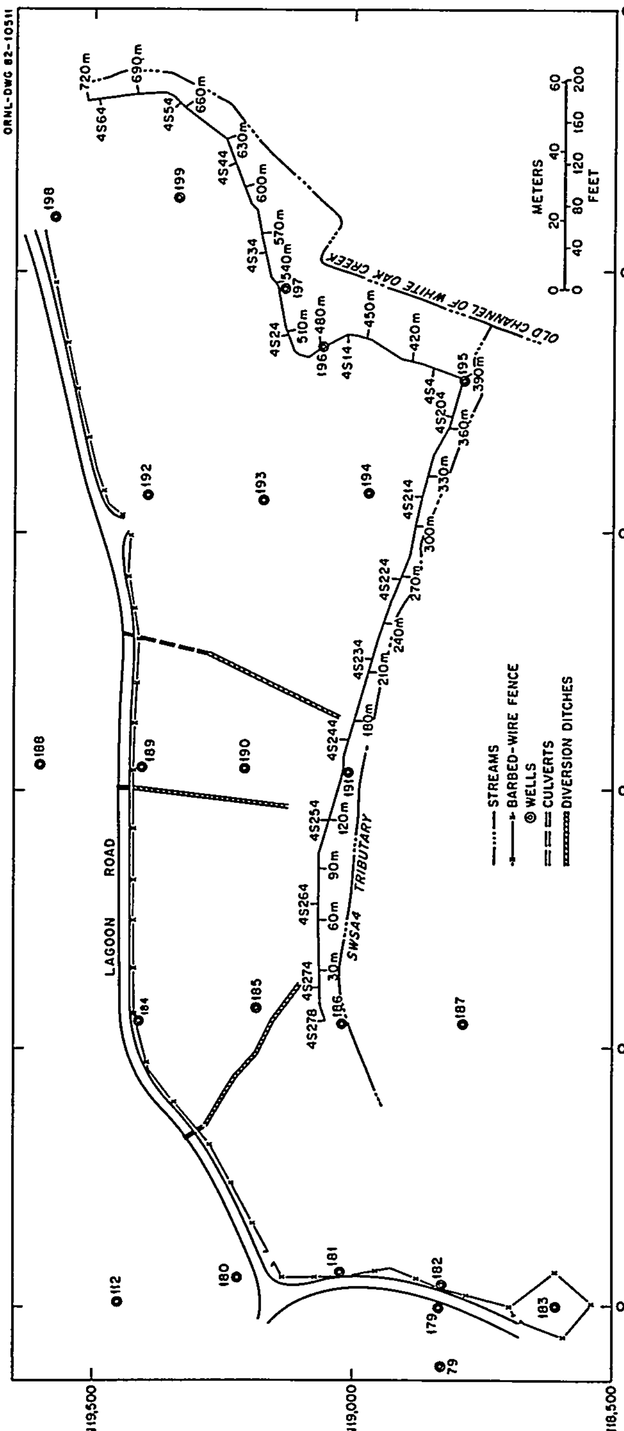


Fig. 11 Groundwater sampling perimeter line on the southern and eastern sides of SWSA-4.

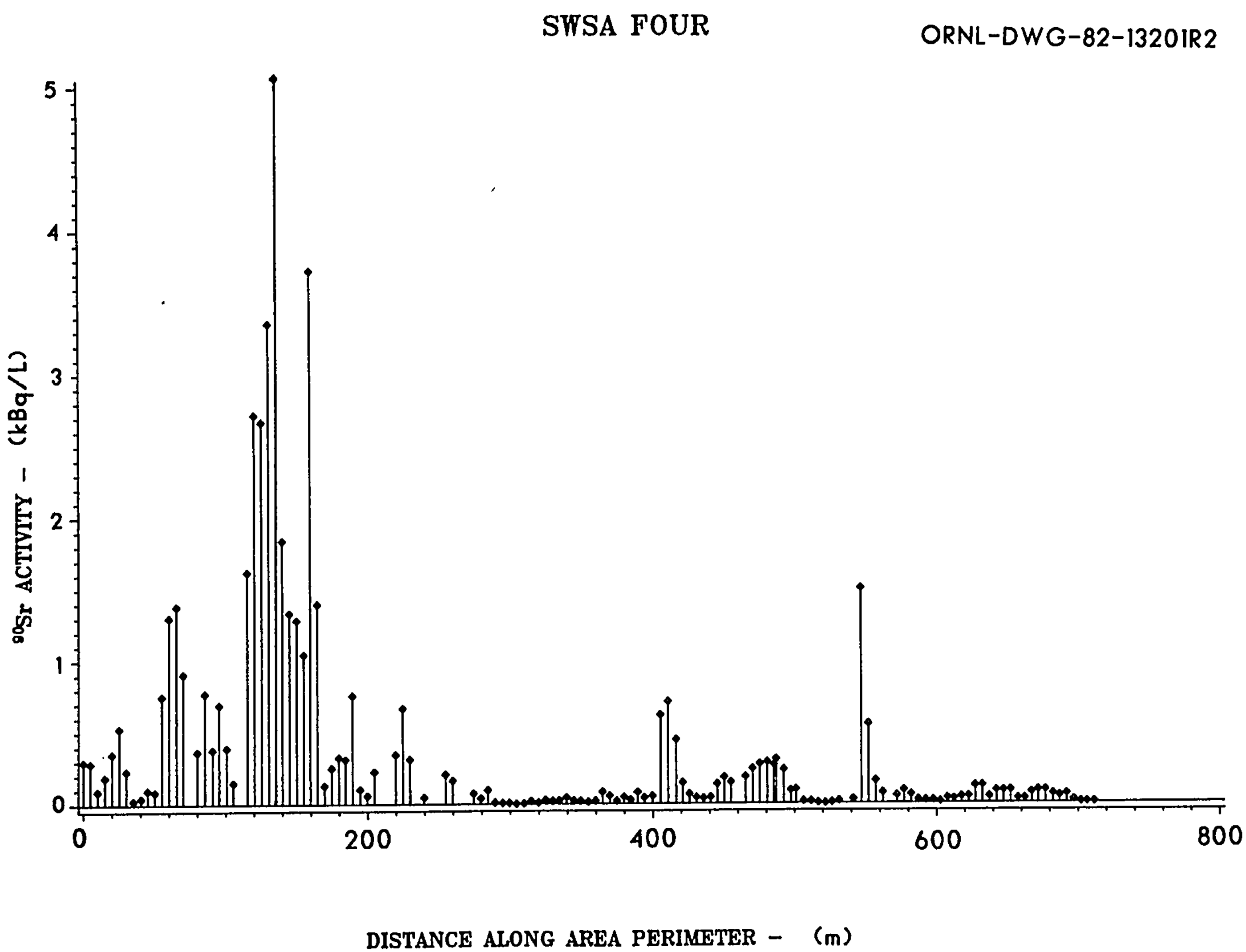


Fig. 12 Concentration of S90TSr in groundwater samples collected along the perimeter of SWSA-4 at the locations depicted in Fig. 11.

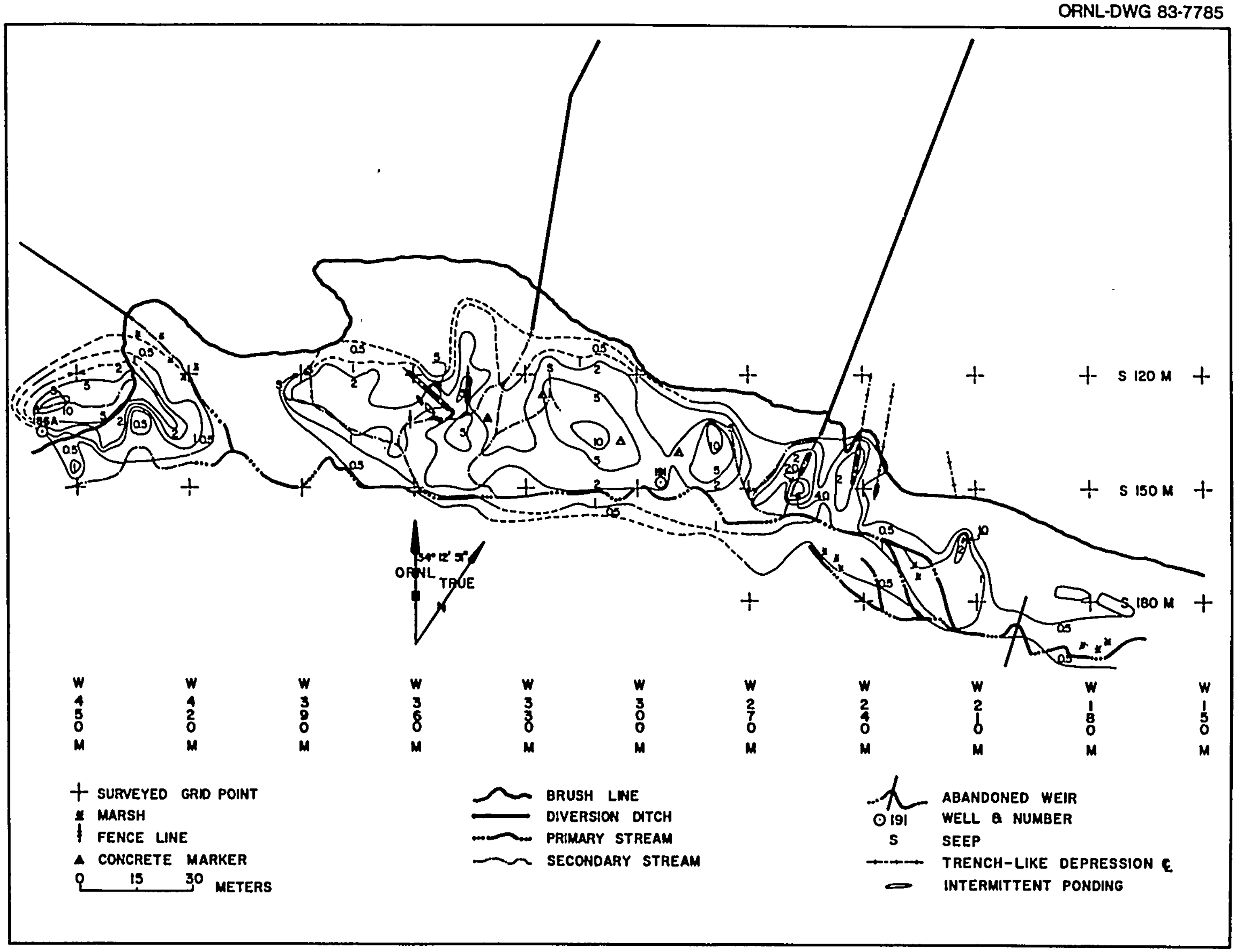


Fig. 13 Results of gross radiation (counts/min) survey of SWSA-4 soil.

Soil samples were taken from selected stations and analyzed for ^{60}Co, ^{137}Cs, and ^{90}Sr. The results of the ^{90}Sr analysis are summarized in Fig. 14 and show a number of seep areas with surface contamination as high as 51,000 pCi ^{90}Sr/g. Concentrations of ^{137}Cs and ^{60}Co in the soil were as high as 10,000 pCi/g and 100 pCi/g, respectively. Additional analysis of radionuclide concentration with depth of soil has pointed out that the contamination is generally confined to a depth of less than 100 cm and results from surface discharge from bathtubbing trenches.

In 1978 Cerling and Spalding (1981, 1982) measured concentrations of ^{60}Co, ^{90}Sr, and ^{137}Cs in streambed gravels of the White Oak Creek Watershed, which included the SWSA-4 tributary. Results indicated that the tributary gravels contained ^{60}Co at a concentration between 1000 and 10,000 dis min^{-1} g^{-1}, ^{90}Sr >500 dis min^{-1} g^{-1}, and ^{127}Cs between 100 and 1,000 dis min^{-1} g^{-1}. These studies served to substantiate previous measurements of these radionuclides in the SWSA-4 tributary and to provide a relative comparison with the concentrations present in creeks draining other areas at ORNL.

3.5 Ecology

The primary vegetation surrounding the SWSA-4 site is the oak-hickory association. It is typified by extensive stands of mixed yellow pine and hardwoods as well as oak and hickory. Since waste disposal sites were first constructed at ORNL in the 1940s, the existing forest has been cleared, the trenches have been excavated and filled with waste, and the approximate 1 m of soil cover has been seeded to grass to prevent soil erosion. No attempt has been made to reforest the trench areas because of the problems associated with deep-rooted plant species intruding into the waste and bringing radionuclides to the surface. Thus a grass cover has been maintained at SWSA-4, which requires both periodic mowing during the summer and yearly applications of nitrogen-containing fertilizer.

A comprehensive listing of plant species that potentially occur on the Oak Ridge Reservation has been compiled (Mann and Nelson 1976).

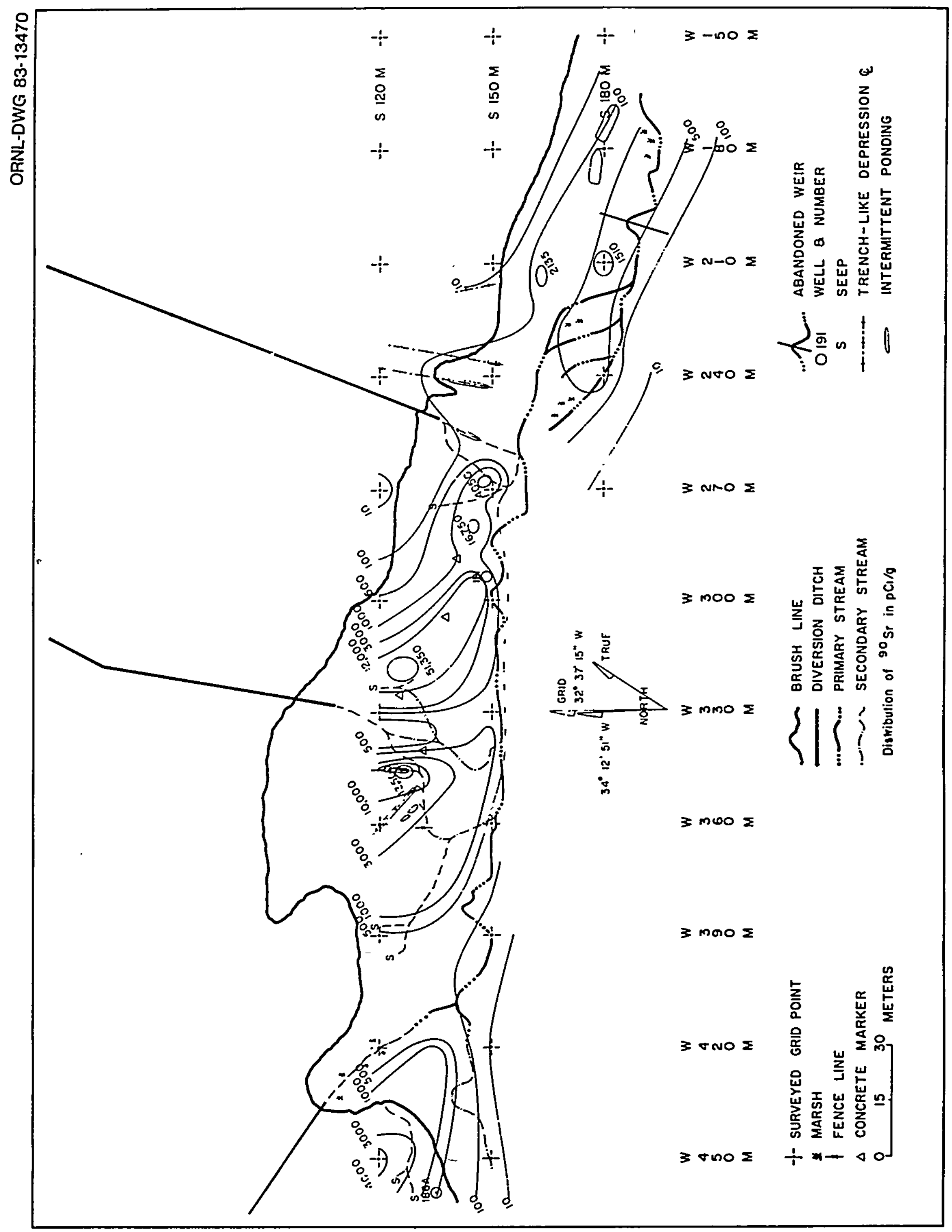


Fig. 14 Distribution of ^{90}Sr in SWSA-4 soil.

There have been no studies on invading species specific to the burial grounds; however, the general pattern of succession of abandoned land is one in which the earliest phase is dominated by annual plants and grasses such as ragweed and crabgrass. The next phase is dominated by biennial and perennial plants such as horseweed, primrose, many species of aster, and other composite. The perennial grass phase, usually dominated by broomsedge, follows. Fescue is dominant at this stage in areas such as power line corridors where it has been planted for erosion control. Areas that are periodically mowed (e.g., SWSA-4), are generally dominated by fescue and other grasses, rapidly growing weedy annuals, and low growing perennials. The grass phase is generally followed by a shrub phase; the grassland is invaded by rapidly growing shrubs, woody vines, and tree seedlings such as sassafras, red cedar, pines, and various hardwoods.

The animal population captured or observed on the Oak Ridge Reservation (and likely to inhabit SWSA-4) consists of small mammals (mice, chipmunks, land shrews), and larger mammals (squirrels, opossum, rats, ground hogs, muskrats, foxes, weasels, bobcats, and deer). Ground hogs in particular have found old waste trenches to make ideal dens. Wooded and open areas as well as edge communities create favorable habitats for a wide variety of bird species.

Mammalian species inhabiting old field or disturbed areas are quite similar, whether the vegetative cover is grass, tree seedlings, or shrubs. In a 1-ha study area indicative of these habitats, the dominant vegetation was tall fescue and sericia lespedeza. Small mammals trapped were cotton rats, white-footed mice, a golden mouse, a rice rat, short-tail shrews, and eastern harvest mice (Kitchings and Mann 1976, Jacobs et.al. 1980).

3.6 Intermediate-Activity Low-Level Liquid Waste Transfer Line

While in use, it is estimated that approximately 170,000 m^3 of liquid waste containing over 1.5 million curies of mixed fission products were transported through this line to the pits and trenches and to the hydrofracture site (Walls et al. 1983). Two major leaks along the line have been identified by Duguid and Sealand (1975) and by Ohnesorge et al. (1981); however, no leaks have been documented along the approximate 730-m length of interest immediately adjacent to SWSA-4.

Radiation measurements at 1-m above the ground and at ground surface (Ohnesorge et al. 1981) were systematically made along the entire transfer line with GM counters equipped with beta shields. The measurements were made directly above the pipeline and 1.5 m to the right and to the left of the line. More than 700 readings were made beginning at the hydrofracture site; although three definite areas defining leaks were identified, those areas adjacent to SWSA-4 typically yielded activity rates of only about 0.04 mR/h, thus indicating no leaks detectable at ground level.

Management of the abandoned intermediate-level liquid waste transfer line has previously been the responsibility of the DOE Surplus Facilities Management Program (Walls et al. 1983). Under the direction of this program, the line was decommissioned over a 2-year period beginning in 1981; decommissioning consisted of (1) removing short sections of pipe that had the potential to leak into White Oak Creek, (2) flushing the line with water and purging with air to remove excess water before capping the ends, and (3) constructing an engineered bentonite clay cover and asphalt cap over two known leak sites in Melton Valley south of SWSA-4. The conclusions of this decommissioning effort were that the line, in its present state, represents only a minor potential source of radionuclide release to the environment, and there is little justification for further remedial measures.

3.7 Experimental Pilot Pit Area

At the time the Pilot Pit Facility was constructed, four wells were drilled to allow groundwater pumping in case a rise in the water table occurred and threatened the experiment. Only one of these water table wells remains (well 183), and water level data are available for 1975 to 1979 (Webster et al. 1981).

Since the sintering experiments were terminated, the area has been used for storage of various field equipment. Large concrete columns were later added to produce municipal solid waste leachate for Environmental Protection Agency-funded studies. At one time the control building was used to machine rock salt samples. The only known radioactivity currently at the site is contained in cores taken during the 1960s Clinch River Study and now stored here.

4. INFORMATION NEEDS AND SUGGESTED ACTIONS

This section considers each of the three units comprising WAG-4 and points out where necessary site information is lacking and what, if anything, might be done to begin collecting this information. It is not the intent to formulate a long-term research program but to suggest actions that can be taken in the short term to acquire information that will be useful to the RI/FS sequence and eventually lead to a strategy for site stabilization. It is only through a review of the existing data, such as that presented in Sect. 3, that data gaps at SWSA-4 can be identified and filled, and the major contaminants, as well as the contaminant pathways, from WAG-4 can be assessed.

4.1 Waste Inventory and Trench Locations

Because most of the records of waste burials in SWSA-4 have been destroyed, there is little information available on the radionuclide content; even less is known of the composition of hazardous chemicals that may also be present. Additional efforts will be required to develop a source term for geohydrologic modeling of the site. One possible approach for obtaining this information would be to locate the records of shipments made from outside sources during the period that SWSA-4 was the Southern Regional Burial Ground. Attempts to develop inventory information using this approach would be time consuming, and even if successful, would not provide information on the waste generated by ORNL, Y-12, and K-25.

The problem of identifying the source term when records are not available is not unique to SWSA-4. Source-term studies initiated in ORNL's SWSA-6 are based on sampling and analysis of trench water and prediction of water flow into and out of the trenches. Because the trench water represents leachate generated by contact of water with the buried waste, radionuclides and hazardous chemicals present in the trench water can be considered representative of contaminants that would be capable of migration from the trench. Sampling both the water in the trench and the groundwater immediately adjacent to the trench would also provide some indication of attenuation of contaminants by SWSA-4 soils. It is suggested that more detailed sampling and analysis of trench water in SWSA-4 be conducted to provide this missing source-term information.

Although drawings exist that show the approximate location of SWSA-4 trenches and the areas reported to be covered with concrete caps (Fig. 6), it appears that additional information on the orientation, size, and location of the trenches and caps will be required for stability analyses and geohydrologic modeling. As indicated in Sect. 4.2, geophysical methods have been proposed that could be used to locate the trenches.

4.2 Geology and Soils

The nature of the burial operations previously conducted at SWSA-4, which included normal trench excavation and fill operations and later the addition of as much as 6 m of construction debris, has left a "geologically disturbed" area. Through the sampling of shallow groundwater around the perimeter of the site and analysis of cores taken within the site itself, it has been demonstrated that radionuclides are leaving the SWSA-4 area via seeps and shallow flow, probably originating from bathtubbing trenches. Information is needed regarding the relative importance of this shallow seepage compared with any deeper movement of contaminated groundwater that may exist. If the presence of contaminants is not found at greater depths, then stabilization techniques can focus entirely on the shallow flow from bathtubbing trenches, thus neglecting any consideration of the deeper flow component.

Trench cover subsidence is a phenomenon that occurs periodically over closed trenches as water-induced movement of the soil cover into trench void space takes place. In stabilizing SWSA-4, trench cover subsidence will need to be minimized to ensure the integrity of any type of trench cover material that may be selected. Methods to minimize future trench cover subsidence of the existing shale cover should be considered and applied before any permanent trench cover is installed.

A retired facility such as SWSA-4 may lend itself to surface geophysical investigations to determine the location of wastes, subsurface structures, voids, rocks, faults, etc. Techniques that could be used for such studies include surface seismic refraction, electrical resistivity, electromagnetic earth conductivity, ground penetrating radar, and gravimeters. Some of these techniques are in the development stages and some have significant limitations; however, for determining exact trench locations, the nature of buried material, or similar characteristics, the application of these techniques should be considered (Rothschild et al. 1985; Cannon et al. 1986).

4.3 Hydrology

Water table measurements previously made by the USGS need to be continued on a monthly basis and should include the newer piezometer wells that have been installed on site (Fig. 6). These data are available for the period 1975 to 1979; however, more recent data that may reflect changes because of the 1983 water diversion project are not yet published. It is suggested that water level monitoring at WAG-4 on wells listed in Table 9 be continued, and the more recent data covering the period 1980 to present should be compiled and published.

Surface flow measured in the SWSA-4 tributary, along with site precipitation records, will be of extreme importance in calculating a water budget for SWSA-4. It is suggested that servicing of the two existing flow measuring stations (T2A and MS1), as well as the SWSA-4 rain gauge, be continued. In addition to routine maintenance of the instruments, it is suggested that the data be made available on a yearly basis through formal reports. It may become advantageous in the future to replace the present punch-tape-type rain gauge with a more sophisticated meteorological station equipped with a data logger such as the one currently operated in SWSA-6.

Table 9. SWSA-4 wells to be included in water level monitoring program

112	179	180	182	183
186	186A	187	188	189
190	190A	190B	190C	191
192	195	196	197	200
201	202	203	402	407
410	676	679	680	681
682	683	684	685	686
687	688	689	690	708
712	718	719	720	724
787	A1	A4	A5	A6
A7	A10	A12	A15	A17
A19	A21	A22	A24	A27
A29	A31	A34	A35	A37

The area in need of the most immediate attention in SWSA-4 is water quality. Previous investigations of water quality have been short term, and no monitoring program has yet been established (for the site) that allows investigation of longer-term trends. The contribution of radionuclides in the SWSA-4 tributary from direct trench leachate, as opposed to groundwater recharge, has not yet been established. Stainless steel (RCRA quality) wells should be installed at selected points in WAG-4, including the locations suggested in Fig. 6. These water quality wells would be in addition to the PVC piezometers being installed, and would facilitate regulatory sampling for water quality (inorganics, organics, and radionuclides) that is not possible with the existing steel and PVC wells. Water sampling should be on at least a quarterly basis and, like data collected under other activities, should be reported on a regular basis. Stream samples from the SWSA-4 tributary should be included to compare the quality of groundwater with that of surface runoff. Such a water quality monitoring program would initiate the collection of data that would be used to evaluate future remedial actions at the site.

4.4 Ecology

The ecology of the SWSAs at ORNL has been described (see Sect. 3.5). SWSA-4 is maintained with a grass cover throughout and is cared for on that basis with periodic mowing and care as necessary. Further studies pertaining to the ecology of this site are probably unnecessary unless laws and regulations are enacted to require such action.

4.5 Intermediate-Activity Low-Level Liquid Waste Transfer Line

As previous experience has shown, the major environmental concern of the intermediate-activity low-level liquid waste transfer lines has been leakage at pipe joints during operation. Since the lines adjacent to SWSA-4 are no longer in use, such leakage under pressure flow is of no concern. The line itself, and whatever residual radioactivity it contains, still represents a potential source of contamination that must be considered. For example, in September 1981 during the line decommissioning activities, radiation measurements taken on exposed sections of the line near White Oak Creek were on the order of 25 to 30 mR/h. Measurements made on the interior of the pipe ranged from 8 to 10 R/h, indicating the presence of a significant amount of beta emitters (Walls et al. 1983). The potential for line deterioration and radionuclide leaching to area groundwater will remain a consideration until the entire line is either removed or stabilized in place.

In considering the monitoring requirements of the intermediate-activity low-level liquid waste transfer line located adjacent to SWSA-4, the surface and groundwater diversion project described in Sect. 2.7 plays a key role. Along an approximate 430-m length of the transfer line located north of Lagoon Road, a crushed stone drainage system was constructed to direct surface runoff and shallow groundwater flow around SWSA-4 (Fig. 7). This drain is within 1 m of the abandoned transfer line and would collect any water coming in contact with the line and divert it to the surface either to the west or east of SWSA-4. The discharge points of this underground drain represent ideal locations to sample for radionuclides that may be leaching from the transfer line. It is suggested that such sampling take place on a quarterly basis to evaluate the potential for leaching of residual radionuclides. Sampling can discontinued as the line is eventually stabilized.

As a final action to be taken to stabilize the decommissioned intermediate-activity low-level liquid waste transfer line, it is suggested that an engineering study be made of the feasibility of either completely removing the pipe or filling the line with grout. Grouting is probably the most logical alternative and could be accomplished in the same manner as the 1981 water flushing of the line. Grouting would result in much less worker exposure when compared to complete line removal. Grouting would also fill any holes that are known to exist in the line due to deterioration and would prevent the line from acting as a conduit for water in the future.

4.6 Experimental Pilot Pit Area

The only radioactivity at the site should be that contained in the stored Clinch River cores. If radioactivity is present on or under the site, it would result from operations outside the site. In 1980 some contamination was found near the north edge of the asphalt pad (adjacent to SWSA-4); this contamination has been removed. No R&D activities have been reported that would make the Pilot Pit Area a source for the release of radioactive or nonradioactive contaminants. The presence or absence of contaminants can be verified by performing a surface contamination survey and by sampling the well within the area.

4.7 Summary of Information Needs

Past research activities carried out in SWSA-4 have identified key areas that need to be considered in planning for the stabilization and eventual closure of the site. For example, water management and control has been found to be of paramount importance and must be addressed in an overall strategy to control radionuclide migration. Subsidence of trench covers and the stabilization of fill material brought to the site and placed over trenches is another area where engineering alternatives need to be considered. Finally, various provisions for long-term maintenance and surveillance of the site need to be considered that can be achieved at a reasonable cost. By considering each of these major areas, a site characterization and closure strategy for SWSA-4 can be developed which meets current performance standards. The following list of specific information needs has been compiled through examining previous studies related to WAG-4. Specific methods of addressing these needs, in addition to a time schedule and cost estimate, have been omitted to allow maximum flexibility in planning on the part of the RI/FS contractor responsible for the site.

A. SWSA-4

Geology and Soils

1. Determine the relative importance of bathtubbing trenches and deeper groundwater flow to the release of contaminants.
2. Determine a method to minimize future trench cover subsidence.
3. Use appropriate geophysical techniques to locate waste trenches.

Hydrology

1. Continue the water table monitoring program.
2. Continue the collection of streamflow and precipitation data.
3. Install RCRA type wells and initiate a water quality monitoring program.

B. Intermediate-Activity Low-Level Liquid Waste Transfer Line

1. Initiate a quarterly water quality monitoring program of the diversion drain that receives drainage from the abandoned line.
2. Investigate the feasibility of grouting the line in place.

C. Experimental Pilot Pit Area

1. Conduct a radiological survey of Building 7811 and the surrounding grounds.

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Appendix A

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APPENDIX A

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APPENDIX B

WATER LEVEL DATA JUNE 1983 TO DECEMBER 1985

GROUND WATER ELEVATION

SITE: SWSA4

DATE: June 3, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.45	239.37
CR3	237.55	237.53
CR4	236.48	236.46
CR5	235.44	235.40
CH3	236.67	237.43
CH4	235.86	235.96
CH5	235.50	235.61
CH6	237.17	237.71
CH7	239.57	240.47
CH8	239.06	239.23
CH9	238.33	238.49
CH10	237.87	238.21
CH10A	238.05	238.21
CH10B	237.97	238.24
CH11I	239.48	239.99
CH11O	239.50	239.99
CH12	240.50	240.45
CH14I	240.99	240.93
CH14O	240.99	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: July 13, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.46	239.37
CR3	-999.00	237.53
CR4	-999.00	236.46
CR5	-999.00	235.40
CH3	236.68	237.43
CH4	235.71	235.96
CH5	235.45	235.61
CH6	236.96	237.71
CH7	239.09	240.47
CH8	238.32	239.23
CH9	238.31	238.49
CH10	237.81	238.21
CH10A	238.04	238.21
CH10B	238.10	238.24
CH11I	239.48	239.99
CH11O	239.36	239.99
CH12	240.48	240.45
CH14I	240.75	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: August 11, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.41	239.37
CR3	-999.00	237.53
CR4	-999.00	236.46
CR5	-999.00	235.40
CH3	236.65	237.43
CH4	235.64	235.96
CH5	235.39	235.61
CH6	236.81	237.71
CH7	238.96	240.47
CH8	238.12	239.23
CH9	238.30	238.49
CH10	237.80	238.21
CH10A	238.02	238.21
CH10B	238.01	238.24
CH11I	239.47	239.99
CH11O	239.27	239.99
CH12	240.45	240.45
CH14I	240.75	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: September 8, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.46	239.37
CR3	-999.00	237.53
CR4	-999.00	236.46
CR5	-999.00	235.40
CH3	236.62	237.43
CH4	235.36	235.96
CH5	235.27	235.61
CH6	236.64	237.71
CH7	238.83	240.47
CH8	237.98	239.23
CH9	238.27	238.49
CH10	237.69	238.21
CH10A	237.98	238.21
CH10B	237.88	238.24
CH11I	239.47	239.99
CH11O	239.22	239.99
CH12	240.44	240.45
CH14I	240.76	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: October 6, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.43	239.37
CR3	-999.00	237.53
CR4	-999.00	236.46
CR5	-999.00	235.40
CH3	236.59	237.43
CH4	235.49	235.96
CH5	235.19	235.61
CH6	236.19	237.71
CH7	239.11	240.47
CH8	238.05	239.23
CH9	238.22	238.49
CH10	237.61	238.21
CH10A	237.93	238.21
CH10B	-999.00	238.24
CH11I	239.46	239.99
CH11O	239.31	239.99
CH12	240.41	240.45
CH14I	240.78	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: November 3, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.48	239.37
CR3	237.54	237.53
CR4	236.47	236.46
CR5	235.44	235.40
CH3	236.57	237.43
CH4	235.77	235.96
CH5	235.22	235.61
CH6	236.66	237.71
CH7	239.02	240.47
CH8	238.50	239.23
CH9	238.20	238.49
CH10	237.58	238.21
CH10A	237.75	238.05
CH10B	237.42	238.05
CH11I	239.46	239.99
CH11O	239.53	239.99
CH12	240.40	240.45
CH14I	240.92	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: December 1, 1983

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.47	239.37
CR3	237.57	237.53
CR4	236.47	236.46
CR5	235.45	235.40
CH3	236.44	237.43
CH4	235.85	235.96
CH5	235.27	235.61
CH6	236.87	237.71
CH7	239.83	240.47
CH8	239.14	239.23
CH9	238.19	238.49
CH10	237.57	238.21
CH10A	237.74	238.05
CH10B	237.71	238.05
CH11I	239.46	239.99
CH11O	239.81	239.99
CH12	240.38	240.45
CH14I	241.19	240.93
CH14O	241.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: January 5, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.47	239.37
CR3	237.55	237.53
CR4	236.45	236.46
CR5	235.46	235.40
CH3	236.32	237.43
CH4	235.78	235.96
CH5	235.30	235.61
CH6	237.12	237.71
CH7	239.81	240.47
CH8	239.10	239.23
CH9	238.19	238.49
CH10	237.61	238.21
CH10A	237.73	238.05
CH10B	237.72	238.05
CH11I	239.47	239.99
CH11O	239.72	239.99
CH12	240.37	240.45
CH14I	241.11	240.93
CH14O	241.01	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: February 9, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.45	241.44
CR2	239.46	239.37
CR3	237.55	237.53
CR4	236.42	236.46
CR5	235.45	235.40
CH3	236.36	237.43
CH4	235.75	235.96
CH5	235.32	235.61
CH6	237.12	237.71
CH7	239.60	240.47
CH8	239.07	239.23
CH9	238.18	238.49
CH10	237.63	238.21
CH10A	237.73	238.05
CH10B	237.66	238.05
CH11I	239.47	239.99
CH11O	239.67	239.99
CH12	240.36	240.45
CH14I	241.11	240.93
CH14O	241.02	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: March 8, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.47	239.37
CR3	237.55	237.53
CR4	236.44	236.46
CR5	235.45	235.40
CH3	236.34	237.43
CH4	235.75	235.96
CH5	235.45	235.61
CH6	237.14	237.71
CH7	239.72	240.47
CH8	239.11	239.23
CH9	238.18	238.49
CH10	237.64	238.21
CH10A	237.73	238.05
CH10B	237.71	238.05
CH11I	239.47	239.99
CH11O	239.74	239.99
CH12	240.35	240.45
CH14I	241.08	240.93
CH14O	241.05	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: April 6, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.48	239.37
CR3	237.55	237.53
CR4	236.45	236.46
CR5	235.45	235.40
CH3	236.50	237.43
CH4	235.76	235.96
CH5	235.45	235.61
CH6	237.19	237.71
CH7	239.95	240.47
CH8	239.13	239.23
CH9	238.18	238.49
CH10	237.66	238.21
CH10A	237.73	238.05
CH10B	237.75	238.05
CH11I	239.47	239.99
CH11O	239.93	239.99
CH12	240.34	240.45
CH14I	241.12	240.93
CH14O	241.08	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: May 3, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.52	241.44
CR2	239.61	239.37
CR3	237.66	237.53
CR4	236.52	236.46
CR5	235.50	235.40
CH3	237.07	237.43
CH4	235.79	235.96
CH5	235.44	235.61
CH6	237.16	237.71
CH7	239.68	240.47
CH8	239.24	239.23
CH9	238.18	238.49
CH10	237.66	238.21
CH10A	237.73	238.05
CH10B	237.79	238.05
CH11I	239.46	239.99
CH11O	239.95	239.99
CH12	240.33	240.45
CH14I	241.15	240.93
CH14O	241.08	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: June 14, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.45	239.37
CR3	237.56	237.53
CR4	236.42	236.46
CR5	235.41	235.40
CH3	236.77	237.43
CH4	235.60	235.96
CH5	235.43	235.61
CH6	236.94	237.71
CH7	239.29	240.47
CH8	238.44	239.23
CH9	238.17	238.49
CH10	237.65	238.21
CH10A	237.70	238.05
CH10B	237.41	238.05
CH11I	239.47	239.99
CH11O	239.47	239.99
CH12	240.33	240.45
CH14I	240.83	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: July 16, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.45	241.44
CR2	239.48	239.37
CR3	237.54	237.53
CR4	236.44	236.46
CR5	235.43	235.40
CH3	237.17	237.43
CH4	235.72	235.96
CH5	235.41	235.61
CH6	236.95	237.71
CH7	239.36	240.47
CH8	238.88	239.23
CH9	238.11	238.49
CH10	237.60	238.21
CH10A	237.68	238.05
CH10B	237.69	238.05
CH11I	239.47	239.99
CH11O	239.72	239.99
CH12	240.32	240.45
CH14I	241.01	240.93
CH14O	241.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: August 6, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.50	239.37
CR3	237.54	237.53
CR4	236.43	236.46
CR5	235.43	235.40
CH3	237.35	237.43
CH4	235.74	235.96
CH5	235.41	235.61
CH6	237.06	237.71
CH7	239.53	240.47
CH8	238.85	239.23
CH9	238.17	238.49
CH10	237.61	238.21
CH10A	237.69	238.05
CH10B	237.72	238.05
CH11I	239.47	239.99
CH11O	239.76	239.99
CH12	240.32	240.45
CH14I	240.97	240.93
CH14O	241.01	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: September 4, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.48	239.37
CR3	237.57	237.53
CR4	236.43	236.46
CR5	235.42	235.40
CH3	237.28	237.43
CH4	235.65	235.96
CH5	235.40	235.61
CH6	236.94	237.71
CH7	239.25	240.47
CH8	238.45	239.23
CH9	238.15	238.49
CH10	237.58	238.21
CH10A	237.68	238.05
CH10B	237.42	238.05
CH11I	239.47	239.99
CH11O	239.51	239.99
CH12	240.31	240.45
CH14I	240.87	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: October 9, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.48	239.37
CR3	237.57	237.53
CR4	236.43	236.46
CR5	235.42	235.40
CH3	237.15	237.43
CH4	235.64	235.96
CH5	235.34	235.61
CH6	236.73	237.71
CH7	238.98	240.47
CH8	-999.00	239.23
CH9	238.13	238.49
CH10	237.50	238.21
CH10A	237.64	238.05
CH10B	237.43	238.05
CH11I	239.47	239.99
CH11O	239.43	239.99
CH12	240.30	240.45
CH14I	240.86	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: November 20, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.48	239.37
CR3	237.58	237.53
CR4	236.43	236.46
CR5	235.54	235.40
CH3	237.39	237.43
CH4	235.74	235.96
CH5	235.37	235.61
CH6	237.08	237.71
CH7	239.85	240.47
CH8	239.13	239.23
CH9	238.13	238.49
CH10	237.54	238.21
CH10A	237.65	238.05
CH10B	237.80	238.05
CH11I	239.48	239.99
CH11O	239.82	239.99
CH12	240.29	240.45
CH14I	241.08	240.93
CH14O	241.01	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: December 12, 1984

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.49	241.44
CR2	239.49	239.37
CR3	237.58	237.53
CR4	236.43	236.46
CR5	235.44	235.40
CH3	237.16	237.43
CH4	235.73	235.96
CH5	235.38	235.61
CH6	237.08	237.71
CH7	239.68	240.47
CH8	239.09	239.23
CH9	238.13	238.49
CH10	237.57	238.21
CH10A	237.66	238.05
CH10B	237.79	238.05
CH11I	239.47	239.99
CH11O	239.75	239.99
CH12	240.28	240.45
CH14I	241.05	240.93
CH14O	241.01	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: January 14, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.48	239.37
CR3	237.55	237.53
CR4	236.42	236.46
CR5	235.43	235.40
CH3	236.93	237.43
CH4	235.75	235.96
CH5	235.40	235.61
CH6	237.10	237.71
CH7	239.84	240.47
CH8	239.09	239.23
CH9	238.12	238.49
CH10	237.59	238.21
CH10A	237.67	238.05
CH10B	237.82	238.05
CH11I	239.48	239.99
CH11O	239.85	239.99
CH12	240.29	240.45
CH14I	241.11	240.93
CH14O	241.02	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: February 4, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.47	241.44
CR2	239.49	239.37
CR3	237.56	237.53
CR4	236.42	236.46
CR5	235.42	235.40
CH3	237.38	237.43
CH4	235.75	235.96
CH5	235.42	235.61
CH6	237.13	237.71
CH7	240.04	240.47
CH8	239.13	239.23
CH9	238.13	238.49
CH10	237.61	238.21
CH10A	237.67	238.05
CH10B	237.81	238.05
CH11I	239.48	239.99
CH11O	239.94	239.99
CH12	240.28	240.45
CH14I	241.10	240.93
CH14O	241.05	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: March 4, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.48	241.44
CR2	239.49	239.37
CR3	237.56	237.53
CR4	236.40	236.46
CR5	235.41	235.40
CH3	237.26	237.43
CH4	235.71	235.96
CH5	235.44	235.61
CH6	237.16	237.71
CH7	239.83	240.47
CH8	239.11	239.23
CH9	238.13	238.49
CH10	237.64	238.21
CH10A	237.68	238.05
CH10B	237.84	238.05
CH11I	239.48	239.99
CH11O	239.85	239.99
CH12	240.28	240.45
CH14I	241.08	240.93
CH14O	241.05	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: April 1, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.49	241.44
CR2	239.50	239.37
CR3	237.55	237.53
CR4	236.41	236.46
CR5	235.40	235.40
CH3	237.20	237.43
CH4	235.71	235.96
CH5	235.43	235.61
CH6	237.09	237.71
CH7	239.49	240.47
CH8	239.10	239.23
CH9	238.12	238.49
CH10	237.64	238.21
CH10A	237.69	238.05
CH10B	237.79	238.05
CH11I	239.48	239.99
CH11O	239.81	239.99
CH12	240.28	240.45
CH14I	241.08	240.93
CH14O	241.05	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: May 6, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.50	239.37
CR3	237.55	237.53
CR4	236.39	236.46
CR5	235.43	235.40
CH3	237.19	237.43
CH4	235.70	235.96
CH5	235.42	235.61
CH6	236.99	237.71
CH7	239.33	240.47
CH8	238.92	239.23
CH9	238.13	238.49
CH10	237.64	238.21
CH10A	237.70	238.05
CH10B	237.67	238.05
CH11I	239.48	239.99
CH11O	239.63	239.99
CH12	240.27	240.45
CH14I	240.90	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: June 10, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.49	239.37
CR3	237.54	237.53
CR4	236.42	236.46
CR5	235.42	235.40
CH3	237.17	237.43
CH4	235.67	235.96
CH5	235.39	235.61
CH6	236.82	237.71
CH7	239.08	240.47
CH8	238.57	239.23
CH9	238.13	238.49
CH10	237.60	238.21
CH10A	237.69	238.05
CH10B	237.53	238.05
CH11I	239.49	239.99
CH11O	239.48	239.99
CH12	240.26	240.45
CH14I	240.85	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: July 3, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.45	239.37
CR3	237.55	237.53
CR4	236.43	236.46
CR5	235.41	235.40
CH3	237.11	237.43
CH4	235.69	235.96
CH5	235.37	235.61
CH6	236.79	237.71
CH7	239.06	240.47
CH8	238.62	239.23
CH9	238.11	238.49
CH10	237.57	238.21
CH10A	237.68	238.05
CH10B	237.58	238.05
CH11I	239.48	239.99
CH11O	239.73	239.99
CH12	240.22	240.45
CH14I	240.88	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: August 12, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.48	239.37
CR3	237.54	237.53
CR4	236.44	236.46
CR5	-999.00	235.40
CH3	237.07	237.43
CH4	235.55	235.96
CH5	235.37	235.61
CH6	236.79	237.71
CH7	239.03	240.47
CH8	238.33	239.23
CH9	238.10	238.49
CH10	237.53	238.21
CH10A	237.66	238.05
CH10B	237.47	238.05
CH11I	239.48	239.99
CH11O	239.49	239.99
CH12	240.25	240.45
CH14I	240.77	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: September 10, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.57	239.37
CR3	237.61	237.53
CR4	236.45	236.46
CR5	235.42	235.40
CH3	237.34	237.43
CH4	235.71	235.96
CH5	235.36	235.61
CH6	237.09	237.71
CH7	239.63	240.47
CH8	238.82	239.23
CH9	238.10	238.49
CH10	237.56	238.21
CH10A	237.68	238.05
CH10B	237.69	238.05
CH11I	239.48	239.99
CH11O	239.67	239.99
CH12	240.25	240.45
CH14I	240.92	240.93
CH14O	240.97	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: October 7, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.47	239.37
CR3	237.62	237.53
CR4	236.45	236.46
CR5	235.42	235.40
CH3	237.30	237.43
CH4	235.69	235.96
CH5	235.36	235.61
CH6	237.05	237.71
CH7	239.42	240.47
CH8	238.77	239.23
CH9	238.10	238.49
CH10	237.55	238.21
CH10A	237.67	238.05
CH10B	237.69	238.05
CH11I	239.48	239.99
CH11O	239.75	239.99
CH12	240.26	240.45
CH14I	240.89	240.93
CH14O	-999.00	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: November 11, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	-999.00	241.44
CR2	239.47	239.37
CR3	237.61	237.53
CR4	236.45	236.46
CR5	235.44	235.40
CH3	236.69	237.43
CH4	235.72	235.96
CH5	235.38	235.61
CH6	236.93	237.71
CH7	239.40	240.47
CH8	238.86	239.23
CH9	238.10	238.49
CH10	237.56	238.21
CH10A	237.68	238.05
CH10B	237.78	238.05
CH11I	239.49	239.99
CH11O	239.81	239.99
CH12	240.26	240.45
CH14I	240.99	240.93
CH14O	241.03	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

GROUND WATER ELEVATION

SITE: SWSA4

DATE: December 9, 1985

SITE	WATER SURFACE ELEVATION	GROUND SURFACE ELEVATION
CR1	241.45	241.44
CR2	239.49	239.37
CR3	237.61	237.53
CR4	236.45	236.46
CR5	235.44	235.40
CH3	237.36	237.43
CH4	235.70	235.96
CH5	235.39	235.61
CH6	237.08	237.71
CH7	239.67	240.47
CH8	239.06	239.23
CH9	238.10	238.49
CH10	237.58	238.21
CH10A	237.68	238.05
CH10B	237.84	238.05
CH11I	239.49	239.99
CH11O	239.86	239.99
CH12	240.26	240.45
CH14I	241.05	240.93
CH14O	241.08	240.93

NOTE: A WATER SURFACE ELEVATION OF -999 DENOTES A DRY WELL.

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